REPORT

ON THE SCIENTIFIC RESULTS

OF THE

"MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION 1910

CARRIED OUT UNDER THE AUSPICES OF THE NORWEGIAN GOVERNMENT AND THE SUPERINTENDENCE OF

SIR JOHN MURRAY, K. C. B.
and DR. JOHAN HJORT

VOLUME I

PUBLISHED BY THE TRUSTEES OF THE
BERGEN MUSEUM

JOHN GRIEG, BERGEN

REPORT

ON THE SCIENTIFIC RESULTS

OF THE

"MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION 1910

CARRIED OUT UNDER THE AUSPICES OF THE NORWEGIAN GOVERNMENT AND THE SUPERINTENDENCE OF

SIR JOHN MURRAY, K. C. B.
and DR. JOHAN HJORT

VOLUME I

PUBLISHED BY THE TRUSTEES OF THE
BERGEN MUSEUM

JOHN GRIEG, BERGEN

CONTENTS.

REPORT ON THE

DEPOSIT-SAMPLES

COLLECTED DURING THE

"MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION 1910

PREPARED UNDER THE SUPERINTENDENCE OF

THE LATE **SIR JOHN MURRAY**, K. C. B.,

BY

JAMES CHUMLEY, F. R. S. G. S.
SECRETARY IN THE CHALLENGER OFFICE, EDINBURGH
NOW ASSISTANT TO THE PROFESSOR OF ZOOLOGY
IN THE UNIVERSITY OF GLASGOW.

The deposit-samples and rock specimens brought home by the "Michael Sars" were received in the Challenger Office shortly after the return of the expedition, and upon examination the rock specimens proved to be so numerous and to offer so many points of interest that Dr. B. N. Peach, F. R. S., was requested to report upon them. A brief note on his results appeared in "The Depths of the Ocean" (London, Macmillan, 1912), pp. 202—209, and his detailed report was published in the Proc. Roy. Soc. Edin., vol. XXXII., pp. 262—291, 1912.

When I met Dr. Hjort in London in May 1914 he desired me to prepare, for publication in the series of Reports on the scientific Results of the "Michael Sars" North Atlantic Expedition, descriptions of the deposit-samples, including for each station a brief summary of Dr. Peach's observations on the rock-specimens obtained. The accompanying Report shows that the "Michael Sars" expedition has made a notable contribution to our knowledge regarding the materials covering the floor of the North Atlantic Ocean.

DETAILED DESCRIPTIONS OF THE "MICHAEL SARS" DEPOSIT-SAMPLES.

Square brackets [ ] are used to indicate percentages arrived at by inspection; parentheses ( ) are used to indicate percentages which are the result of chemical analysis.

"Michael Sars" **Station 1.** 9th April, 1910.
Lat. 49° 27′ N., Long. 8° 36′ W.; Depth—157 m. (86 fms.)

BLUE MUD: greenish-grey when wet, light grey with greenish tinge when dry, slightly coherent.

CALCIUM CARBONATE [40 per cent.]:—one or two small pelagic Foraminifera, bottom-living Foraminifera, Mollusc fragments, Echinoid shell fragments and spines, Polyzoa, Crustacean claw fragments, Ostracods, coccoliths.

RESIDUE [60 per cent.], green:—

Siliceous Organisms [3 per cent.]; Sponge spicules, Radiolaria, Diatoms.

Minerals [25 per cent.]; m.di. 0·14 mm., rounded, quartz, felspar, mica, a few glauconitic grains.

Fine Washings [32 per cent.]; amorphous clayey matter with minute mineral particles.

"Michael Sars" **Station 4.** 10th April, 1910.
Lat. 49° 27′ N., Long. 8° 36′ W.; Depth—1000 m. (547 fms.).

GLOBIGERINA OOZE: dirty grey when wet, light grey when dry, coherent, granular; not typical because of the abundance and variety of bottom-living Foraminifera.

CALCIUM CARBONATE [70 per cent.]:—Pelagic Foraminifera [40 per cent.]: *Orbulina*, *Globigerina*, *Pulvinulina* mostly of small size; bottom-living Foraminifera [25 per cent.]: *Biloculina*, *Uvigerina* very abundant, *Miliolina*, *Rotalia*, etc.; other organisms [5 per cent.]: Pteropod fragments, Echinoid shell fragments and spines, Gasteropod and Lamellibranch fragments, Ostracods, coccoliths, one or two coccospheres.

RESIDUE [30 per cent.], brown:—

Siliceous Organisms [3 per cent.]; arenaceous Foraminifera (abundant), Radiolaria, one or two Diatoms, imperfect casts.

Minerals [15 per cent.]; m.di. 0·12 mm., mostly rounded, quartz, mica, magnetite, felspar.

Fine Washings [12 per cent.]; amorphous clayey matter with minute mineral particles.

From this station Dr. Peach records a piece of coal briquette, three clinker fragments, and small piece of coal, all evidently fallen overboard from ships.

„Michael Sars" **Station 10.** 19th to 21st April, 1910.
Lat. 45° 26′ N., Long. 9° 20′ W. (Bay of Biscay); Depth—4700 m. (2567 fms.).

GLOBIGERINA OOZE: fawn colour, finely granular, coherent.

CALCIUM CARBONATE (66·11 per cent.):—Pelagic and bottom-living Foraminifera, Echinoid spines, Ostracods, Pteropod fragments, one or two coccospheres, many coccoliths.

RESIDUE (33.89 per cent.):—

Siliceous Organisms [1 per cent.]; arenaceous Foraminifera, Radiolaria, Diatoms.

Minerals [1 per cent.]; angular and rounded, m.di. 0.12 mm., quartz, acid plagioclase, hornblende, olivine, magnetite, biotite, a fragmentof volcanic glass with minute microliths, fragments of rocks about 1 mm. in diameter, a decomposed ferruginous mineral.

Fine Washings [31.89 per cent.]; amorphous clayey matter with minute particles of minerals.

Note: The sounding-tube at this station sank into the deposit to the depth of 12 cm. or nearly 5 inches. The upper portion of the sample to the depth of about 3 inches was of a uniform fawn colour and represented apparently an ordinary Globigerina Ooze with 66 per cent. of calcium carbonate, whereas the lower one or two inches had a mottled appearance with light and dark brown patches, being here and there almost pure white in colour and quite chalky. A rough attempt to analyse a little of the white material gave 70 per cent. of calcium carbonate, but the white material could not be separated from a certain proportion of the brown material. A sufficient quantity of the dark brown material was separated and gave on analysis 33 per cent. of calcium carbonate. Apart from these variations in the amount of calcium carbonate, microscopic analysis showed very little difference between the differently coloured portions of the sample. The detailed description above, therefore, deals only with the upper homogeneous portion of the roll from the sounding-tube. In addition to the material from the sounding-tube the trawl brought up a large bag full of Globigerina Ooze like the upper portion of the roll already described. From this source small pebbles were washed out,

From this station Dr. Peach records more than three hundred rock specimens, mostly glaciated, varying from $^1/_8$ to over 2 inches in greatest diameter, together with eighty pieces of clinkers, cinders and coal. The sedimentary rocks include greywacke, grit, limestone, shale and chalk; the metamorphic rocks include gneiss and schist; and among igneous rocks there are granite, diorite, gabbro, quartz-syenite, dolerite, and basalt.

"Michael Sars" **Station 19.** 2nd May, 1910.
Lat. 36° 5′ N., Long 4° 42′ W. (Mediterranean Sea); Depth—1000 m. (547 fms.).

BLUE MUD: greenish-grey, coherent, fine-grained, lustrous streak.

CALCIUM CARBONATE (16·9 per cent.):—pelagic and bottom-living Foraminifera.

RESIDUE (83.1 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules.

Minerals [3 per cent.]; mostly angular, m. di. 0·08 mm., quartz, orthoclase, decomposed glass.

Fine Washings [79·1 per cent.]; clayey matter with minute mineral particles.

Note: A section about 4 inches in length, of uniform appearance throughout, came up in the sounding-tube (lead tube, Iversen's patent).

"Michael Sars" **Station 20.** 5th May, 1910.
Lat. 35° 25′ N., Long. 6° 25′ W. (Straits of Gibraltar); Depth—153 m. (84 fms.).

BLUE MUD: brownish-grey, granular, coherent, with large fragments of Mollusc shells embedded in the deposit.

CALCIUM CARBONATE (33·06 per cent.):—pelagic and bottom-living Foraminifera, Echinoid shell fragments and spines, Mollusc fragments, Ostracods, one or two coccoliths, one or two Pteropod fragments.

RESIDUE: (66·94 per cent.):—

Siliceous Organisms [1 per cent.]; Radiolaria, Sponge spicules, glauconitic casts.

Minerals [50 per cent.]; angular and rounded, m. di. 0·12 mm., principally quartz, with a few grains of glauconite, decomposed felspar and a ferruginous mineral; mica.

Fine Washings [15·94 per cent.]; clayey matter with minute mineral particles.

Note: The material examined was obtained by the trawl, but was quite coherent and showed no signs of having been washed in any way. It was therefore taken to represent the deposit at the bottom.

"Michal Sars" **Station 21.** 5th May, 1910.
Lat. 35° 31′ N., Long. 6° 35′ W; Depth—535 m. (293 fms.).

BLUE MUD: brownish, extremely coherent and clayey, lustrous streak.

CALCIUM CARBONATE (27·24 per cent.):—pelagic and bottom-living Foraminifera, fragments of Pteropods, Gasteropods and Lamellibranchs, Echinoid spines, Ostracods, and a very few coccoliths and rhabdoliths.

RESIDUE (72·76 per cent.):—

Siliceous Organisms [1 per cent.]; fragments of arenaceous Foraminifera.

Minerals [3 per cent.]; rounded and angular, m. di. 0·08 mm., quartz, orthoclase.

Fine Washings [68·76 per cent.]; mostly very minute mineral particles with amorphous clayey matter.

Note: The material here described was obtained by the trawl. A few shells of *Dentalium* and other Molluscs were visible here and there, embedded in the clayey matrix. The mineral particles exceeding 0.05 mm. in diameter are few in number.

"Michael Sars" **Station 23.** 5th-6th May, 1910.
Lat. 35° 32′ N., Long. 7° 7′ W.; Depth—1215 m. (664 fms.).

At this station apparently no sounding was taken, but the Petersen net was sent down with 1500 metres (820 fathoms) of line and hauled throughout the night between the 5th and 6th of May. When hauled up it was found to contain a very large amount of empty Pteropod shells, the principal species being *Hyalea inflexa*, with here and there *Cleodora pyramidata* and other species of Pteropods, Lamellibranch shells, arenaceous and other bottom-living Foraminifera, Sponge spicules and Worm tubes.

From this station Dr. Peach records two pieces of clinker, the larger, over six inches in length, having a simple coral attached, and from Station 24, 1615 metres (883 fathoms), three pieces of clinker having siliceous Sponges, Serpulae, and Brachiopods attached.

"Michael Sars" **Station 25 A.** 7th May, 1910.
Lat. 35° 36′ N., Long. 8° 25′ W.; Depth—2300 m. (1256 fms.).

GLOBIGERINA OOZE: fawn colour, finely granular, coherent.

CALCIUM CARBONATE (50.73 per cent.):—pelagic and bottom-living Foraminifera, Ostracods, Pteropod fragments, coccoliths, one or two rhabdoliths.

RESIDUE (49.27 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, small fragments of arenaceous Foraminifera.

Minerals [1 per cent.]; angular and rounded, m. di. 0.07 mm., quartz, plagioclase, volcanic glass, mica.

Fine Washings [47.27 per cent.]; clayey matter with minute mineral particles.

Note: A section of deposit about $2^1/_2$ inches in length of uniform appearance throughout came up in the sounding-tube.

"Michael Sars" **Station 25 B.** 8th May, 1910.
Lat. 35° 46′ N., Long. 8° 16′ W.; Depth—2055 m. (1122 fms.).

GLOBIGERINA OOZE: fawn colour, finely granular, coherent.

CALCIUM CARBONATE (40·73 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, Pteropod fragments, coccoliths, one or two rhabdoliths.

RESIDUE (59·27 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, fragments of arenaceous Foraminifera.

Minerals [1 per cent.]; angular and rounded, m. di. 0.07 mm., quartz, decomposed glass, decomposed ferruginous mineral, plagioclase, magnetite (?).

Fine Washings [57·27 per cent.]; clayey matter with minute mineral particles.

Note: A section of deposit about $2^1/_4$ inches in length of uniform appearance throughout came up in the sounding-tube. The trawl brought up a large bag of material, which upon examination did not differ from the sample described from the sounding-tube, an analysis giving 37·05 per cent. of calcium carbonate.

From this station Dr. Peach records four large specimens of *Balanus porcatus*, and the two valves of an American oyster evidently thrown overboard from an Atlantic liner.

"Michael Sars" **Station 34.** 13th-14th May, 1910.
Lat. 28° 52′ N., Long. 14° 16′ W.; Depth — 2170 m. (1185 fms.).

PTEROPOD OOZE: fawn coloured, coherent.

CALCIUM CARBONATE (71·48 per cent.):— pelagic and bottom-living Foraminifera, Pteropods, Heteropods, and fragments of other Molluscs, Ostracods, Tunicate spicules, coccoliths and rhabdoliths.

RESIDUE (28·52 per cent.):—

Siliceous Organisms [3 per cent.]; Sponge spicules, arenaceous Foraminifera, Diatoms, Radiolaria, imperfect casts.

Minerals [10 per cent.]; angular, m. di. 0·11 mm., principally brown volcanic glass, some pieces vesicular, others with a minute corded structure showing slightly birefringent fibres; quartz, orthoclase, plagioclase, augite, hematite, magnetite, mica, and a doubtful green mineral.

Fine Washings [15·52 per cent.]; amorphous clayey matter, with small mineral particles.

Note: The sounding-tube brought up a roll about 11 inches in length, which appeared fairly uniform throughout, having the usual fawn colour characteristic of a Globigerina or Pteropod Ooze; the Pteropods could be quite plainly seen at the upper end. About the middle of the roll, i. e. about 6 inches below the upper surface, dark patches were visible which upon examination proved to contain a large proportion of volcanic glass quite fresh and unaltered, as though the products of a volcanic eruption (probably submarine, since the glassy fragments show no trace of friction but are perfectly angular) had been overlain by new material to the depth of about 6 inches.

"Michael Sars" **Station 35.** 18th-19th May, 1910.
Lat. 27° 27′ N., Long. 14° 52′ W.; Depth—2603 m. (1422 fms.).

GLOBIGERINA OOZE: fawn coloured, finely granular, coherent.

CALCIUM CARBONATE (52·08 per cent.):— pelagic and bottom-living Foraminifera, Pteropod fragments, coccoliths and rhabdoliths.

RESIDUE (47·92 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules.

Minerals [3 per cent.]; angular and rounded, m. di. 0·07 mm., quartz, mica.

Fine Washings [43·92 per cent.]; amorphous clayey matter with small mineral particles.

Note: The material from the sounding-tube formed a roll about 7 inches in length, and in certain parts Pteropod fragments were visible to the naked eye.

"Michael Sars" **Station 37.** 20th May, 1910.
Lat. 26° 6′ N., Long. 14° 33′ W.; Depth — 47 m. (26 fms.).

This sample consists of a portion of the "arming" from the sounding-lead, in which are embedded Mollusc shells and fragments, arenaceous and other bottom-living Foraminifera, and mineral particles.

"Michael Sars" **Station 37.** 20th May, 1910.
Lat. 26° 6′ N., Long. 14° 33′ W.; Depth — 42 m. (23 fms.).

This sample consists of a portion of the "arming" of the lead, in which are embedded Mollusc shells and their fragments, otoliths of Fishes, bottom-living Foraminifera, Bryozoa, Echinoid spines, mineral particles, etc.

"Michael Sars" **Station 41.** 23rd May, 1910.
Lat. 28° 8′ N., Long 13° 35′ W.; Depth — 1365 m. (746 fms.).

GLOBIGERINA OOZE: fawn colour, coherent.

CALCIUM CARBONATE (57·02 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, coccoliths, rhabdoliths.

RESIDUE (42·98 per cent).:—

Siliceous Organisms [1 per cent.]; arenaceous Foraminifera and fragments, Sponge spicules.

Minerals [1 per cent.]; only one or two quartz grains exceeding 0·05 mm. in diameter were observed.

Fine Washings [40·98 per cent.]; clayey matter with many minute mineral particles.

"Michael Sars" **Station 47.** 30th May, 1910.
Lat. 29° 2′ N., Long. 22° 53′ W.; Depth —5160 m. (2817 fms.).

GLOBIGERINA OOZE: fawn coloured, finely granular, coherent.

CALCIUM CARBONATE (60·99 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, coccoliths, rhabdoliths.

RESIDUE (39·01 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, fragments of Radiolaria.

Minerals [2 per cent.]; mostly angular, m. di. 0·07 mm., quartz, mica.

Fine Washings [36·01 per cent.]; amorphous clayey matter with small mineral particles.

Note: The sounding-tube brought up a roll about 13 inches in length of uniform appearance throughout.

„Michael Sars" **Station 48.** 31st May, 1910.
Lat. 28° 54′ N., Long. 24° 14′ W.; Depth — not stated.

The only material received is an earbone of a whale, much corroded, the traces of deposit adhering to it indicating apparently a Globigerina Ooze. Unlike nearly all the earbones dredged by the „Challenger", no trace of manganese could be seen on this one.

From this station Dr. Peach records two chips of chalk-flint, a small fragment of epidiorite or hornblende schist, ice-moulded and coated with manganese peroxide, four fragments of decomposed basalt, and over sixty rounded fragments of pumice.

"Michael Sars" **Station 49 C.** 1st-2nd June, 1910.
Lat. 29° 7′ N., Long. 25° 32′ W.; Depth — 5425 m. (2966 fms.).

GLOBIGERINA OOZE: fawn coloured, finely granular, coherent.

CALCIUM CARBONATE (64·31 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, Ostracods, coccoliths and rhabdoliths.

RESIDUE (35·69 per cent.):—

Siliceous Organisms [less than 1 per cent.]; only one or two broken Sponge spicules were observed during the examination of the material.

Minerals [less than 1 per cent.]; only one or two mineral particles exceeding 0·05 mm. in diameter could be detected — apparently all quartz.

Fine Washings [33·69 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube had sunk deeply into the deposit and brought up a section about 14 inches in length. As frequently happens when such a long section is brought up, traces of stratification were distinctly visible, more especially towards the upper end, although the lower end presents quite a mottled appearance with patches of lighter and darker brown. Towards the upper end small patches were observed of a dark brown colour, which upon examination proved to be Red Clay, a small portion analysed giving only 25·08 per cent. of calcium carbonate. This Red Clay, however, forms but an insignificant proportion of the total sample, the deposit being in reality a Globigerina Ooze as in the detailed description, which is based upon material taken from the middle of the section. This sounding, the deepest cast made during the cruise, suggests the proximity of an unknown "deep", or an extension southwards of the Monaco Deep.

"Michael Sars" **Station 51.** 5th-6th June, 1910.
Lat. 31° 20′ N., Long. 35° 7′ W.; Depth — 3886 m. (2121 fms.).

GLOBIGERINA OOZE: light fawn or cream coloured, granular.

CALCIUM CARBONATE (87·58 per cent.):— pelagic and bottom-living Foraminifera, Echinoid spines, coccoliths, rhabdoliths, primordial cells of Foraminifera.

RESIDUE (12·42 per cent.):—

Siliceous Organisms [less than 1 per cent.]; one or two splinters of Sponge spicules.

Minerals [less than 1 per cent.]; only one or two mineral particles exceeding 0·05 mm. in diameter could be detected, apparently all quartz.

Fine Washings [10·42 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube at this Station sank deeply into the deposit, the outside being marked for a distance of about 46 cm. (about 18 inches), but the sample received is about 10 cm. (4 inches) in length, and apparently uniform throughout.

"Michael Sars" **Station 53.** 8th June, 1910.
Lat. 34° 59′ N., Long 33° 1′ W; Depth—2615 m. (1428 fms.).

GLOBIGERINA OOZE: dirty white colour, coherent, granular.

CALCIUM CARBONATE (92·15 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, coccoliths, rhabdoliths.

RESIDUE (7·85 per cent.):—

Siliceous Organisms [2 per cent.]: Sponge spicules, Radiolaria, arenaceous Foraminifera, Diatoms.

Minerals [less than 1 per cent.]; only one or two colourless particles exceeding 0·05 mm. in diameter were observed.

Fine Washings [4·85 per cent.]; amorphous clayey matter with minute mineral particles too small for identification.

Note: The sounding-tube brought up a roll about 8 inches in length of a uniform almost white colour. Marks were observed outside the tube for a distance of 50 cm. (20 inches).

"Michael Sars" **Station 54.** 10th June, 1910.
Lat. 35° 37′ N., Long. 30° 15′ W.; Depth—3185 m. (1739 fms.).

GLOBIGERINA OOZE: dirty white colour, coherent, granular.

CALCIUM CARBONATE (84·93 per cent.):—pelagic and bottom-living Foraminifera, Ostracods, coccoliths and rhabdoliths.

RESIDUE (15·07 per cent.]:—

Siliceous Organisms [1 per cent.]; Sponge spicules, Radiolaria, Diatoms.

Minerals [1 per cent.]; m.di. 0·06 mm., angular, orthoclase (?), volcanic glass, decomposed ferruginous mineral.

Fine Washings [13·07 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 6 inches in length of a uniform creamy white colour. Marks were observed outside the tube for a distance of 54 cm. (about 21 inches).

"Michael Sars" **Station 55.** 10th June, 1910.
Lat. 36° 24′ N., Long. 29° 52′ W.; Depth—3239 m. (1768 fms.).

GLOBIGERINA OOZE: dirty white colour, coherent, granular.

CALCIUM CARBONATE (78·59 per cent.);—pelagic and bottom-living Foraminifera, Ostracods, coccoliths and rhabdoliths.

RESIDUE (21·41 per cent.):—

Siliceous Organisms [2 per cent.]; Radiolaria, Sponge spicules.

Minerals [4 per cent.]; m.di. 0·09 mm., one angular fragment of volcanic glass exceeded 2 mm. in length; quartz, plagioclase, volcanic glass, augite (?), magnetite, mica.

Fine Washings [15·41 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 9 inches in length of a creamy white colour throughout.

"Michael Sars" **Station 56.** 10th-11th June, 1910.
Lat. 35° 53′ N., Long. 29° 47′ W.; Depth—3239 m. (1768 fms.).

GLOBIGERINA OOZE: creamy white, granular, coherent.

CALCIUM CARBONATE (71·25 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, Ostracods, coccoliths, rhabdoliths.

RESIDUE (28·75 per cent.):—

Siliceous Organisms [2 per cent.]; Sponge spicules, Radiolaria.

Minerals [4 per cent.]; mostly angular, m.di. 0·09 mm., quartz and mica.

Fine Washings [22·75 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 9 inches in length of a creamy white colour and apparently uniform throughout.

"Michael Sars" **Station 58.** 12th June, 1910.
Lat. 37° 37′ N., Long. 29° 25′ W.; Depth—1015 m. (555 fms.).

Apparently all that came up in the sounding-tube at this Station were a few fragments of peroxide of manganese and of Fish otoliths, with one or two attached organisms (Foraminifera, etc.).

"Michael Sars" **Station 63.** 22nd June, 1910.
Lat. 36° 5′ N., Long. 43° 58′ W.; Depth—5035 m. (2749 fms.).

GLOBIGERINA OOZE: dark fawn coloured, granular, slightly coherent.

CALCIUM CARBONATE (53·16 per cent.):—pelagic Foraminifera, coccoliths, a few coccospheres and rhabdoliths.

RESIDUE (46·84 per cent.]:—

Siliceous Organisms [2 per cent.]; Radiolaria, Sponge spicules, and fragments of arenaceous Foraminifera.

Minerals [less than 1 per cent.]; only one or two particles exceeding 0·05 mm. in diameter were observed, augite, felspar (partly decomposed).

Fine Washings [43·84 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 12 inches in length. In the small portion examined no bottom-living Foraminifera were observed. This station is near the two "Challenger" stations 66 and 67, and the above description agrees very closely with that of "Challenger" station 67, where coccospheres and rhabdoliths were not observed, but where bottom-living Foraminifera, Ostracod valves and Echinoid spines were recorded.

"Michael Sars" **Station 70.** 30th June, 1910.
Lat. 42° 59′ N., Long. 51° 15′ W.; Depth—1100 m. (601 fms.).

From this Station Dr. Peach records seven rock fragments, including mudstone, limestone, calcareous sandstone, amphibolite, dolerite, and basalt.

"Michael Sars" **Station 88.** 18th July, 1910.
Lat. 45° 26′ N., Long. 25° 45′ W.; Depth—3120 m. (1703 fms.).

GLOBIGERINA OOZE: dirty white, slightly coherent, granular.

CALCIUM CARBONATE (73·66 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, fragments of Molluscs, coccoliths and rhabdoliths.

RESIDUE (26·34 per cent.):—

Siliceous Organisms [3 per cent.]; Diatoms, Radiolaria, Sponge spicules, fragments of arenaceous Foraminifera.

Minerals [20 per cent.]; m.di. 0·15 mm., angular and rounded, quartz, orthoclase, mica.

Fine Washings [3·34 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 14 inches in length, which showed little difference to the naked eye, although the colour was darker in the lower portion, the upper portion being rather lighter in colour, less coherent, and more granular. The percentage of calcium carbonate given in the above description is from the middle portion of the section. Material from near the bottom and from near the top of the roll gave respectively 62·1 per cent. and 83·79 per cent. of calcium carbonate. Here and there rock fragments are visible to the naked eye, the largest observed being a fragment of limestone, 5 by 3 inches in diameter.

From this station there are also three bags of material, evidently collected by the trawl, consisting principally of Pteropods (chiefly *Hyalea trispinosa*) and their fragments, intermixed with pelagic and bottom-living Foraminifera, Fish otoliths, Echinoid spines, etc. In view of this large supply of Pteropods it is curious to note that in the small sample from the sounding-tube examined no Pteropods were observed.

From this station Dr. Peach records some pieces of wood-charcoal, and four pieces of wood bored by *Teredo*.

"Michael Sars" **Station 91.** 22nd July, 1910.
Lat. 47° 32′ N., Long. 16° 38′ W.; Depth—4922 m. (2688 fms.).

GLOBIGERINA OOZE: dirty white, slightly coherent, granular.

CALCIUM CARBONATE (67·16 per cent.):—pelagic and bottom-living Foraminifera, fragments of Echinoid spines, coccoliths and rhabdoliths.

RESIDUE (32·84 per cent·):—

Siliceous Organisms [2 per cent.]; Radiolaria, Diatoms, fragments of arenaceous Foraminifera.

Minerals [less than 1 per cent.]; mostly angular, m.di. 0·08 mm., only one or two particles of volcanic glass (?) observed.

Fine Washings [29·84 per cent.]; amorphous clayey matter with minute fragments of minerals.

Note: The sounding-tube brought up a roll about 6 inches in length, apparently uniform throughout.

"Michael Sars" **Station 93.** 25th July, 1910.
Lat. 50° 13′ N., Long. 11° 23′ W.; Depth—1257 m. (688 fms.).

GLOBIGERINA OOZE: grayish colour, coherent, granular.

CALCIUM CARBONATE (53·16 per cent.):—pelagic and bottom-living Foraminifera, Echinoid spines, coccoliths and coccospheres, one or two rhabdoliths.

RESIDUE (46·84 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, Radiolaria.

Minerals [10 per cent.]; angular and rounded, m.di. 0·08 mm., appear to be all quartz and mica.

Fine Washing [35·84 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 7 inches in length, apparently uniform throughout.

"Michael Sars" **Station 95.** 26th July, 1910.
Lat. 50° 22′ N., Long. 11° 44′ W.; Depth—1797 m. (981 fms.).

GLOBIGERINA OOZE: gray, coherent.

CALCIUM CARBONATE (63·17 per cent.):— pelagic and bottom-living Foraminifera, Echinoid spines, Ostracods, coccoliths.

RESIDUE (36·83 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, Radiolaria, imperfect casts.

Minerals [2 per cent.]; angular and rounded, m.di. 0·09 mm.; quartz, felspar.

Fine Washings [33·83 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The sounding-tube brought up a roll about 9 inches in length. From this station Dr. Peach records over two hundred rock fragments, distributed probably by natural agencies, as well as a large quantity of furnace-slag, pieces of pottery, and the cannon bone of an ox, probably thrown overboard from ships. Among the sedimentary rock fragments are greywacke, sandstone, shale, lydian-stone, quartzite, limestone, calcareous shale, chalk, chalk-flint, dolomite, and vein quartz; of metamorphic rocks there are gneiss, schist, slate, phyllite, felsite and epidiorite; igneous rocks include granite, nepheline syenite, lamprophyre, dolerite, and basalt.

"Michael Sars" **Station 98.** 5th August, 1910.
Lat. 56° 33′ N., Long. 9° 30′ W.; Depth—1360 m. (742 fms.).

GLOBIGERINA OOZE: darkish gray, granular, slightly coherent.

CALCIUM CARBONATE (40·73 per cent.):— pelagic and bottom-living Foraminifera, Echinoid spines, coccoliths and coccospheres.

RESIDUE (59·27 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, imperfect casts.

Minerals [30 per cent.], mostly rounded, m.di. 0·1 mm.; almost entirely quartz and mica, no other species being determinable.

Fine Washings [28·27 per cent.]; amorphous clayey matter with minute mineral particles.

Note: Only a very small sample was available from this Station.

"Michael Sars" **Station 100.** 6th August, 1910.
Lat. 57° 48′ N., Long. 12° 43′ W.; Depth—1530 m. (835 fms.).

LOWER PORTION.

BLUE MUD: gray with a tinge of brown, clayey, coherent, contains macroscopic rock fragments and Mollusc shells.

CALCIUM CARBONATE (26·22 per cent.):— small pelagic Foraminifera and a few bottom-living forms, Echinoid spines, Ostracods.

RESIDUE (73·78 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules.

Minerals [30 per cent.]; angular and rounded, m.di. 0·15 mm., the deposit includes many rock fragments, ranging from the merest splinters to a fragment about half an inch in diameter, quartz, colourless glass, brown glass, plagioclase, decomposed ferruginous mineral, tourmaline, biotite.

Fine Washings [42·78 per cent.]; amorphous clayey matter with minute mineral particles.

UPPER PORTION.

GLOBIGERINA OOZE: gray, a little lighter in colour than the lower portion, slightly coherent, granular.

CALCIUM CARBONATE (58·14 per cent.):— small pelagic Foraminifera and a few bottom-living forms, Echinoid spines, Ostracods, coccoliths and a few coccospheres.

RESIDUE (41·86 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, imperfect casts.

Minerals [30 per cent.]; more variable in size and generally more rounded and larger than those in the lower portion, quartz tinged red, quartz with green choloritic tinge, minute fragments of black and red slaggy lava, decomposed ferruginous mineral, volcanic giass, tourmaline, magnetite, biotite, chalcedony, purple-brown augite, orthoclase; a doubtful grain of glauconite observed.

Fine Washings [10·86 per cent.]; amorphous clayey matter with minute mineral particles.

Note: The material from the sounding-tube formed a section about 9 inches long, and was interesting because of the difference between the upper and lower portions. No very distinct separation-line could be observed, but the upper portion to the extent of three or four inches was decidedly more granular and less coherent, and contained a much higher percentage of calcium carbonate than the lower portion. Rock fragments were scattered throughout the whole length of the section, and the proportion of mineral particles exceeding 0·05 mm. in diameter seemed much the same throughout. It thus appears that at this place there is a Blue Mud containing only 26 per cent. of calcium carbonate overlain to the depth of three or four inches by a Globigerina Ooze containing 58 per cent. of calcium carbonate. It is interesting to note also that numerous coccoliths and a few coccospheres were observed in the upper portion, but could not be recognised after continued search in the lower portion. The smaller amount of calcium carbonate in the lower portion is apparently balanced by a proportionately larger amount of amorphous clayey matter.

"Michael Sars" **Station 101.** 6th-7th August, 1910.
Lat. 57° 41′ N., Long. 11° 48′ W.; Depth—1853 m. (1013 fms.).

From this station Dr. Peach records a fragment of flaggy sandstone, four inches in length.

"Michael Sars" **Station 102.** 9th-10th August, 1910.
Lat. 60° 57′ N., Long. 4° 38′ W.; Depth—1098 m. (600 fms.).

BLUE MUD: dark gray with tinge of brown, coherent.

CALCIUM CARBONATE (10·07 per cent.):— small pelagic Foraminifera, bottom-living Foraminifera, fragments of Mollusc shells and of Echinoid spines.

RESIDUE (89·93 per cent.):—

Siliceous Organisms [1 per cent.]; fragments of arenaceous Foraminifera, Diatoms, glauconitic casts.

Minerals [60 per cent.]; angular and rounded, m.di. 0·2 mm., fragments of rocks, (granite, sandstone, schist, limestone, etc., the largest half an inch in diameter), quartz, felspar, mica, magnetite, volcanic glass.

Fine Washings [28·93 per cent.]; amorphous clayey matter with many minute mineral particles.

"Michael Sars" **Station 102.** 9th-10th August, 1910.
Lat. 60° 57′ N., Long. 4° 38′ W.; Depth—1500 m. (820 fms.).

The material from this station consists of a rock fragment about 1½ by 1 inch, (to which arenaceous Foraminifera and Sponges are attached) and a few smaller fragments.

"Michael Sars" **Station 114.** 12th-13th August, 1910.
Lat. 61° 8′ N., Long. 3° 16′ W.; Depth—1047 m. (571 fms.).

BLUE MUD: dark gray with tinge of brown, coherent.

CALCIUM CARBONATE (11·2 per cent.):— pelagic and bottom-living Foraminifera, coccoliths, one or two coccospheres.

RESIDUE (88·8 per cent.):—

Siliceous Organisms [1 per cent.]; Sponge spicules, Diatoms, arenaceous Foraminifera.

Minerals [30 per cent.]; angular and rounded, m.di. 0·2 mm.; mostly quartz, decomposed felspar, decomposed ferruginous mineral, hornblende, mica.

Fine Washings [57·8 per cent.]; amorphous clayey matter with minute mineral particles.

Note: Only a small amount of material was available from this Station, consisting of a pellet of the mud with numerous rock fragments, on one of which (a fragment of banded sandstone, three-quarters of an inch in diameter) an arenaceous Foraminifer was growing.

CONCLUSIONS.

The number of deposit-samples received in the Challenger Office was 35. In one case the depth from which the material (an earbone of a whale) was taken was not stated, but the remaining 34 samples were from depths between 23 and 2966 fathoms, distributed as follows:—

5	samples from depths	less than 500 fathoms;
13	„ „ „	between 500 and 1000 fathoms;
10	„ „ „	„ 1000 „ 2000 fathoms;
6	„ „ „	over 2000 fathoms.
34		

Of the five samples from depths less than 500 fathoms the two shallowest ones (from 23 and 26 fathoms) were tallow "armings" from the sounding lead, in which principally calcareous shell-fragments were embedded, the other three being Blue Muds from 84, 86 and 293 fathoms.

Of the thirteen samples from depths between 500 and 1000 fathoms four were insufficient to determine the type of deposit (in two cases stones and rock fragments being brought up from 601 and 820 fathoms, in one case empty Pteropod shells coming up from 664 fathoms, and in one case grains of manganese and fish otoliths from 555 fathoms), five were Globigerina Oozes from 547, 688, 742, 746 and 981 fathoms, one was Globigerina Ooze overlying Blue Mud from 835 fathoms, and three were Blue Muds from 547, 571 and 600 fathoms.

Of the ten samples from depths between 1000 and 2000 fathoms eight were Globigerina Oozes from 1122, 1256, 1422, 1423, 1703, 1739, 1768 and 1768 fathoms, one was a Pteropod Ooze from 1185 fathoms, and in the remaining case only stones were brought up from 1013 fathoms.

The six samples from depths exceeding 2000 fathoms were Globigerina Oozes from 2121, 2567, 2688, 2749, 2817 and 2966 fathoms.

Of the thirty-five samples eight were insufficient to indicate the deposit type (in three cases stones and rock fragments, in two cases tallow „armings", in one case empty Pteropod shells, in one case the earbone of a whale, and in one case fish otoliths with manganese grains, being all that was available), the remaining twenty-seven being referred to the following types:—

Globigerina Ooze	19
Globigerina Ooze overlying Blue Mud	1
Blue Mud	6
Pteropod Ooze	1
	27

The nineteen Globigerina Oozes range in depth from 547 to 2966 fathoms and are scattered over the North Atlantic as far west as long. 44° W., occurring to the north and south-west of Ireland and out into the open ocean, in the Bay of Biscay, opposite the Straits of Gibraltar, in the vicinity of the Canary Islands, between the Canary Islands and the Azores, and to the south and west of the Azores. The Globigerina Ooze overlying Blue Mud occurred to the north of the Rockall Bank in 835 fathoms.

The six Blue Muds range in depth from 84 to 600 fathoms and occur in the Faroe Channel, to the south of Ireland, in and on both sides of the Straits of Gibraltar, that is to say both inside and outside of the Mediterranean. The single Pteropod Ooze was taken from 1185 fathoms near the Canary Islands.

The modifications necessitated by the inclusion of this series of deposits in the map showing the distribution of deep-sea deposits over the floor of the North Atlantic are: (1) the extension of the Globigerina Ooze area nearer the coasts of the British Islands to the south and south-west, as well as to the north, of Ireland, and its extension also to the north of Rockall Bank; (2) the introduction of both Globigerina Ooze and Pteropod Ooze in the neigbourhood of the Canary Islands where they were previously unrecorded.

An interesting point in connection with the "Michael Sars" deposits is the number of instances where the sounding-tube had plunged deeply into the sediment, bringing up sections varying from two to fourteen inches in length, though in some cases marks observed on the outside of the sounding-tube indicated that it had penetrated still further into the deposit. Though in most cases the material was apparently uniform throughout, some of these long sections gave distinct evidences of stratification. Thus at Station 100 Globigerina Ooze was found overlying Blue Mud. The lower portion of the sample from Station 10 was mottled light and dark brown, the dark portions approaching Red Clay in composition, while the rest of the sample was a characteristic Globigerina Ooze. The upper portion of the Globigerina Ooze from Station 49 C showed similarly patches of lighter and darker brown, the dark brown material proving on analysis to be a Red Clay with less than 30 per cent. of calcium carbonate. The middle portion of the section from Station 34 (Pteropod Ooze) showed dark coloured patches containing a large proportion of volcanic glass splinters, to which the dark colour was due.

Coccoliths were observed in every sample except one from the Mediterranean. Rhabdoliths were noticed in nearly half of the samples, mostly in the eastern portion of the North Atlantic, only two stations (51 and 63) lying to the west of the Azores. Similarly coccospheres were recognised in six samples from the eastern North Atlantic, and in only one sample (Station 63) to the west of the Azores.

In the determination of the mineral species enumerated under the heading of "Minerals" we have had the assistance of Dr. G. W. Lee, of the Geological Survey of Scotland, who remarks that on the whole we are dealing principally with minerals of continental origin with an admixture of volcanic particles, and that quartz occurs at the greatest depths.

The rock-fragments brought up at Station 95, Dr. Peach concludes, are not the debris of rocks *in situ*, but may be matched by rocks occurring in the west of Scotland and northern and western Ireland, and have been transported by floating ice during the period of maximum glaciation. The specimen of nepheline syenite may even have been brought by part of the "polar pack" since glacial times. More than half of the specimens are ice-moulded or well glaciated, and some of the glaciated stones have nests of boulder clay attached to them which must have been transported with the stones. Most of the stones had only about one-third (many of them even less) of their bulk embedded in the ooze, some of the more elongated specimens being embedded on end, and the flat specimens on edge; so that they seem to have been dropped upon, and to have sunk into, a flocculent ooze, until they reached a layer of sufficient tenacity to prevent further sinking, being at first totally buried and subsequently partially exposed as the result of current action. The rock specimens from Station 10, most of them glaciated, are identical with those from Station 95, and evidently derived from the same sources and distributed by the same agencies. The rock fragments from Station 48 appear to indicate the influence of the northern drift ice, although situated south of lat. 30° N. The striated stones from Station 70 have probably been derived from the Arctic regions, since this station is situated in the direct route of the icebergs and pack-ice brought down by the cold current. The sandstone from Station 101 is like the Brenista flags of Shetland, and may have been transported by floating ice beyond the limit of the great ice-sheet.

Referring to the association of these glaciated rock fragments with cinders from steamers Sir John Murray, in a lecture delivered before the Royal Scottish Geographical Society in Edinburgh on 11th November, 1910, made the following interesting remark:— "If steamers using coal should some day be superseded by vessels using some other kind of fuel, then the deposits in the North Atlantic would have a layer which might be called the coal-fuel layer. On the other hand, if the coal-cinders and these glaciated rock fragments are now lying together on the floor of the ocean, geologists may in the remote future find proofs in these layers that man and steamers existed in the glacial period."

PHYSICAL OCEANOGRAPHY

AND

METEOROLOGY

RESULTS OF THE

"MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION 1910

BY

BJØRN HELLAND-HANSEN

FOREWORD

Owing to various circumstances not altogether within my own control, the completion of this paper has been delayed to an extent which I greatly regret, particularly as this has inconvenienced the authors of other parts of the scientific report on the "Michael Sars" Expedition.

Shortly after the termination of the cruise preliminary reports were published on its results, including the researches in physical oceanography. Subsequently communications on certain special geophysical problems were issued from time to time, either in publications or in the form of lectures. A good deal that is contained in this paper may therefore be already known to the reader. In the interval that has elapsed, however, new investigations have furnished us with observations which supplement the "Michael Sars" material, and other progress has been made which has been of value for the final working-up of the results. I have endeavoured to present the subject in a form adapted for biologists as well as geophysicists.

I desire to express my cordial thanks to my friends and colleagues Dr. V. Walfrid Ekman and Dr. H. U. Sverdrup for the help they have rendered me by subjecting parts of the manuscript to critical revision; and also to my assistants for their unremitting and faithful aid.

Bjørn Helland-Hansen.

CONTENTS

PART I (TEXT)

PART II (TABLES AND PLATES)

PHYSICAL OCEANOGRAPHY

AND

METEOROLOGY

PART I (TEXT)

I. INTRODUCTION.

1. The North Atlantic Ocean.

The North Atlantic proper is that part of the Atlantic Ocean which extends from the Equator northwards to the submarine ridge (with islands) between Greenland and Scotland. The Norwegian Sea to the north of this ridge has often been classed as a part of the North Atlantic, but it is now generally admitted that the Norwegian Sea topographically and oceanographically forms a so well defined area that it must be kept distinct from the Atlantic much in the same manner as the North Sea or Baffin's Bay generally are. This distinction will always be maintained in the present paper.

The essential topographic features of the North Atlantic are well known: the central ridge extending as a comparatively narrow, continuous bar from Iceland to the Equator, and thus clearly dividing the ocean into an eastern and a western part: — a series of deeps on both sides of the ridge; — a very irregular bottom configuration in many places, especially conspicuous in the northern part of the ocean between western and southern Europe and the Newfoundland Banks, the area where most soundings have been made. The details will be seen from the chart on p. 63*; it is based upon the thorough mapping by Dr. GROLL. Even the details are of great importance for studying the currents, as will be shown later on.

The basin of the North Atlantic Ocean contains very different kinds of water. The greater part of the water-masses consists of the so-called bottom-water or deep water, filling nearly all the basin below some 2000 metres. The average depth of the North Atlantic is almost 4000 metres. In the upper strata there are great variations from equatorial (or tropical) waters in the south to polar (or arctic) waters in the north, and at intermediate depths the characteristic water from the Mediterranean is traced over great areas in the eastern part of the ocean. The different waters mix and thus form what may be called "Atlantic water". It is subject to variations through different agencies acting upon the sea-surface but may on the whole be characterized by the correlation between temperature and salinity (section 18).

The general circulation in the North Atlantic Ocean — though well known — must, for the sake of clearness, be shortly mentioned here: The North Equatorial Current is joined by a considerable part of the South Equatorial Current N. of Brazil. The water passes partly N. of the Antilles and partly through the Caribbean Sea and the Gulf of Mexico. The excess water from the Gulf passes the Strait of Florida and joins the Antille Current, the whole mass of water flowing (under the name of "The Gulf Stream") along the American coast as far as the southern slope of the Newfoundland Bank. Then it crosses the ocean towards Europe. Part of it branches off towards the north, flowing either towards Iceland or through the Faeroe-Shetland Channel into the Norwegian Sea. The other part of the "Gulf Stream" flows southwards, contributing to the formation of the Canarian Current, which continues into the North Equatorial Current. A great anticyclonic circulation is thus established in the Southern and central part of the North Atlantic. — Polar water flows southwards along the east coast of Greenland, makes at Cape Farewell a turn northwards and — after mixing with polar water from Baffin's Bay — ultimately runs southwards along the coasts of Labrador and Newfoundland as "The Labrador Current". The waters of this surface-current disappear by mixing with the "Gulf Stream", but traces of them may be recognized pretty far to the south along the coast of U.S.A.

2. The Cruise of the "Michael Sars" and the Geophysical Work on Board.

The chief aim of the "Michael Sars" Expedition was to make a general biological survey of the North Atlantic Ocean by means of modern methods and based upon the experience gained by the Norwegian Fisheries' Research. The geophysical investigations could only form a minor part of the programme, and had to take the second place. As much time as the other work permitted was, however, devoted to them.

When planning the work it was decided that the geophysical investigations should embrace a survey of the

distribution of temperature and salinity in the central part of the North Atlantic with its various currents, together with some special investigations, which would fit in with the route and time. Current measurements were to be made, if possible, in the open ocean, especially in order to study the variations of ocean currents vertically and the existence or non-existence of tidal currents over great depths. Such measurements were also to be made in the Straits of Gibraltar. A photometer was constructed for making observations, down to great depths, of the penetration of light-rays of different wave-lengths. By a special agreement with the authorities of the Scottish marine researches it was decided that continuous observations during 24 hours, of possible vertical variations in temperature and salinity should be made in the Faeroe-Shetland Channel simultaneously from the "Michael Sars" and the Scottish research steamer.

The route of the "Michael Sars" is shown in the chart p. 64*. The route covered great areas where previously only a few or no observations had been made by modern methods. The investigations embraced: — the eastern part of the North Atlantic where *e. g.* the influence of the Mediterranean could be studied; — the outskirts of the Sargasso Sea; — different parts of the "Gulf Stream"; — the Newfoundland Bank with the Labrador Current; — the areas on both sides of the Wyville Thomson ridge. It would thus be possible, in a comparatively short space of time, to make a general survey of the North Atlantic with essentially different characteristics.

The demand of simultaneity can, of course, never be fully satisfied by investigations with one vessel only. The "Michael Sars" observations were made between the beginning of April and the middle of August, 1910. The physical conditions at intermediate and at great depths have probably not altered much during these 4 months and may, therefore, be directly comparable for the whole area of investigation. In the upper strata, however, the seasonal variations make a direct combination of the observations from different parts of the cruise very doubtful or even erroneous (cf. Chapter IV).

The observations are published in the Tables I a and b, II, and V. The methods used will be described and further particulars mentioned in subsequent chapters.—

On the starboard side of the ship there were two steam-winches for the hydrographic work and the work with vertical nets for catching small plankton organisms. The foremost winch could be coupled to a big drum and to a Lucas sounding machine. The drum was provided with 5000 m. steel-wire of 3·5 mm. diam., which was used for all hydrographic observations below 2000 m., and also, occasionally, for observations in the upper strata. The other winch was placed amidships and could be coupled to two drums, one of which was used for the hydrographic work at by far the greater number of stations. It was provided with 2000 m. steel-wire of 2·5 mm. diam. The wire was new, and very good to begin with, but after a time it became corroded and worn through constant use in sea-water at relatively high temperatures. Ultimately parts of the wire had to be condemned. Under such circumstances wire of phosphor-bronze is much to be preferred; it will prove cheaper in the long run.

II. THE SEA-SURFACE AND THE AIR.

3. The Surface Observations.

The surface observations were made in the ordinary simple way: water was hawled up in a bucket, the temperature was read, and a glass-bottle filled with a water-sample for titration. The thermometers were divided in $^1/_{10}°$ C. They were so sensitive that they gave the temperature correct within 0·1° C in about half a minute. The sample-bottles and the titrations will be mentioned in section 14.

During the greater part of the cruise the surface-temperature was observed every hour, while water-samples were, as a rule, only taken every second hour. Most of these observations on board were made by the ship's officers G. Wilhelmsen and K. Knudsen.

4. Meteorological Observations.

On the top of the pilot-house of the "Michael Sars" we had a screen for meteorological instruments, of the type generally called the Norwegian Screen. Its sides were open enough to permit the air passing through them, while neither direct sunshine nor rain or spray from the sea could reach the instruments. The screen was placed about 4 metres in front of the funnel; the instruments had a height above sea-level of 5 metres.

A psychrometer stand with dry and wet-bulb thermometers was placed in the screen. From June 3rd to the end of the cruise the thermometers were read by the officers, as a rule every second hour. The air temperature was also sometimes observed by means of a swing-thermometer;

the agreement between this and the dry thermometer in the screen was excellent. The corrected temperatures, as well as the values of relative humidity, are recorded in Table I b; temperatures found by means of the swing-thermometer are printed in *italics*. Sometimes the wet-bulb thermometer gave a slightly higher corrected reading than the dry thermometer of the psychrometer; in these cases the relative humidity is reckoned as 100 and placed within brackets [100].

We had two aneroid barometers and a barograph on board. They were often read, but as they did not give quite trustworthy records the results are omitted in the Tables. Sufficient information on the distribution of pressure may be deduced from the Hoffmeyer charts (edited by The Danish Meteorological Institute and the Deutsche Seewarte in cooperation). Parts of these charts are reproduced on pp. 77*, 79*, 81*, and 83*.

Observations of wind directions were made along with the temperature observations. The directions recorded in Table Ib are magnetic, just as they were noted in the journals[1]). The wind velocity was estimated according to the "half Beaufort" (0—6), a scale which has been preferred by many Norwegian sailors.

The cloudiness was estimated according to the scale 0–10 (0=blue sky, 10=overcast). Fog and rain were noted in the journals. In the column headed "Remarks" in Tables I and Ib, the ciphers indicate the number of the hydrographic stations; F means fog, and R rain.

The work in the small steamer with only few observers on board had to be concentrated upon the essential investigations, and but slight attention could be paid to meteorological investigations during the expedition. To begin with it seemed doubtful whether it would be worth while to publish the observations. Closer examination, however, has shown that the observations give much more interesting results than might be expected and it is strongly to be recommended that such observations every hour or every second hour be more generally made than is now the case.

5. Statistical Treatment of the Observations.

The occasional variations in the meteorological elements tend to obscure the general features. The former may, however, to a great extent be eliminated by means of statistical methods.

When we calculate *continuous means for 24 hours* the daily period and many casual variations disappear, and the more general variations stand out. If we have observations made every hour and calculate the means for all observations between 0^h and 23^h (incl.), between 1^h and 0^h on the following day, between 2^h and 1^h on the next, and so on, we get the means centred at about $11^h\ 30^m$, $12^h\ 30^m$, $13^h\ 30^m$, etc. These means may be termed m_{24}. In order to have them referred to full hours we may take the averages of every two succeeding values, so getting the means for 12^h, 13^h, etc. These means may be termed $m_{24,2}$. By taking the difference $(o-m_{24,2})$ between the single observations (o) and the means referred to the hour of observation $(m_{24,2})$ we get values corresponding to the casual and short-period (*e. g.* the daily) variations. In the case of observations which were only made every second hour, we get similar values by taking continuous means of 12 successive observations, and calculate $m_{12,2}$ and $o-m_{12,2}$ for every second hour [cf. WALLÉN, 1910 and 1913, HELLAND-HANSEN and NANSEN, 1917 and 1920].

Our material of observations from the sea-surface

[1]) The directions may be reduced to true directions by applying the following values of magnetic variation:

Date	Var.	Date	Var.	Date	Var.	Date	Var.	Date	Var.	Date	Var.
V 28	18° W	VI 9	22° W	VI 23	20° W	VII 9	30° W	VII 20	24° W	VIII 5	23° W
„ 29	„ „	„ 10	„ „	„ 24	19° „	„ 10	„ „	„ 21	23° „	„ 6	24° „
„ 30	19° „	„ 11	„ „	„ 25	20° „	„ 11	31° „	„ 22	22° „	„ 7	„ „
VI 1	„ „	„ 12	„ „	„ 26	22° „	„ 12	„ „	„ 23	21° „	„ 8	23° „
„ 2	20° „	„ 13	„ „	„ 27	„ „	„ 13	30° „	„ 24	„ „	„ 9	21° „
„ 3	„ „	„ 17	„ „	„ 28	„ „	„ 14	„ „	„ 25	„ „	„ 10	19° „
„ 4	21° „	„ 18	„ „	„ 29	23° „	„ 15	29° „	„ 26	„ „	„ 11	21° „
„ 5	„ „	„ 19	„ „	„ 30	25° „	„ 16	28° „	„ 27	20° „	„ 12	20° „
„ 6	„ „	„ 20	„ „	VII 1	27° „	„ 17	26° „	„ 28	19° „	„ 13	19° „
„ 7	„ „	„ 21	21° „	„ 2	29° „	„ 18	„ „	„ 29	„ „	„ 14	18° „
„ 8	22° „	„ 22	„ „	„ 8	30° „	„ 19	25° „	VIII 4	21° „	„ 15	16° „

and the air has been treated in this way. Values which were lacking have been interpolated. We have four different series, *viz:*

I. June 3—13 from the area S. of the Azores. The observations commenced at about 30° N, 29° W. At first the route lay westward to about 35° W on June 5 (at Stat. 51) and then, from June 7, in a north-easterly direction towards Fayal.

II. June 17 to July 2 from the Azores WSW to the Sargasso Sea (Stat. 64 on June 24) and thence northwards to Newfoundland.

III. July 8—29 from Newfoundland to the British Isles (through the Irish Sea to Glasgow).

IV. August 4—15 from Glasgow to Rockall, thence to the Faeroe-Shetland Channel (where two cross sections were worked), and finally to Bergen.

The values of $m_{24,2}$ (for the surface temperature) or $m_{12,2}$ (for the other elements) are represented graphically in the figures **A** on pp. 76*, 78*, 80*, and 82*. The curves **B** show the differences $(o-m_{24,2})_3$ or $(o-m_{12,2})_3$. The original differences have been smoothed out by taking continuous means for 3 successive values in order to eliminate many disturbing accidental variations.

In these figures $S^0/_{00}$ denotes the surface salinity, τ_s the surface temperature, τ_a the air temperature, τ_{s-a} the temperature difference between water and air, H_{abs} the absolute humidity (in grams per cubic metre), $H^0/_0$ the relative humidity, C the cloudiness, and W the wind. In the figures **A** the dotted curves W represent the 24-hour means $(m_{12,2})$ of velocity in "half Beaufort" (0—6). The arrows are vectors, giving the true (not magnetic) direction and the velocity for each individual observation. The ordinate represents the south—north direction; the vector-scale of velocity is half the scale for the dotted curve (the latter is given to the left in the figures). Calm weather is denoted by a cross. At the top of the figures **A** will be found some signs representing rain (small vertical lines) and fog (horizontal lines).

For a discussion of the variations in the surface-water and the air it is important to know the meteorological conditions over a wide area. The synoptic charts referred to above (edited by the Danish Meteorological Institute and the Deutsche Seewarte) give sufficient information. Parts of these charts are reproduced along with the curves mentioned. They refer to the morning observations made by many ships and land-stations. In the reproductions will be found data for wind direction and velocity (calm weather denoted by a ring or a dot), air temperature (in whole degrees centigrade, written in heavy type), and sea temperature (in tenth degrees, written in slender type). The air pressure is represented by the isobars for every 5 mm. Fog is denoted by three short horizontal lines. The representation of cloudiness (rings more or less blackened) is very uncertain as in many cases it is impossible to recognize it in the original publication, owing to lack of clearness in the printing. The position of the "Michael Sars" at 8 a.m. is marked by a cross in each chart. The first chart in each series shows the position of the various "Michael Sars" stations, and the dates when they were occupied.

The individual observations given in these charts are of very unequal value, and many of them are possibly or even certainly wrong. Provided, however, that we avoid paying too much attention to the individual details and that we chiefly study the grouping of the general features, we can derive from these reproductions practically all the information necessary for our purpose.

6. The Surface Salinity.

The general variations in surface salinity along the route of the "Michael Sars" will be seen from the **A**-curves marked $S^0/_{00}$, pp. 76*, 78*, 80*, and 82*. These salinity curves have a very even shape with quite small bends, except in some few places. The general geographic features stand out clearly, with small variations within each hydrographically defined region and with large variations at the transitions from one region to another. In the first series (p. 76*) it is a conspicuous feature that the salinity had a high value near the Sargasso Sea, slightly decreasing northwards to the Azores. The second series shows slight variations from the date of start from the Azores up to June 25th. On June 26th the salinity fell rapidly for a short distance, when the route had passed from the "Gulf Stream" into a "bight" of colder and less saline water influenced by the Labrador Current from the north. From the 27th to the 28th of June the "Michael Sars" went first southwards and then northwards again within the "Gulf Stream" area with high salinities. The ship finally left this area on June 29th, and passed into the waters coming from the north along the Newfoundland Banks. The third series (p. 80*) shows the low salinities of the Newfoundland waters (the left side of the curve) and of the coastal waters near the British Isles (to the right), with a long intervening streak of uniform waters with the high salinities characteristic of the "Gulf Stream". Finally, the curve of the last series (p. 82*) indicates the variations in salinity on the passage from the coastal waters near Scotland to the area of the Atlantic current (to the left in the figure), and from the continuation of the same current in the Norwegian Sea to the coastal waters of

Norway. A slight minimum is seen about August 10th, near Shetland.

In this manner the general variations in salinity are fully explained as a consequence of the variations in regions. The casual meteorological variations (*e. g.* in wind-conditions) exert quite a subordinate influence upon these general variations demonstrated by observations from a ship moving at considerable speed and covering great distances.

The more rapid casual, or periodic, variations may be studied by means of the **B**-curves, pp. 76*, 78*, 80*, and 82*. They are drawn on a much larger vertical scale than the **A**-curves. The differences $o - m_{12,2}$ have, as already mentioned, been smoothed by the calculation of continuous means for every 3 successive values.

Great variations were met with in the transitional regions mentioned above: on June 26th, 27th, 29th, July 9th—12th, 27th, 28th, and August 14th. Otherwise the variations were relatively small. There are no conspicuous daily variations to be seen. The maxima, for instance, occurred at any time of day or night. Nor is there any quite definite rhythm in the variations, although a mean period of some 16 hours seems to be possible.

Comparison with the curve *W* shows that there is in many cases some apparent coincidence between the variations in salinity and in wind velocity. On many days a maximum of wind velocity corresponded to a maximum of salinity, but on other days a maximum of wind corresponded to a minimum of salinity. This discrepancy might be accounted for by variations in the direction of the wind, but our observations do not seem to give a clear and definite solution.

It must also be borne in mind that the salinity in many or most cases shows horizontal variations down to considerable depths which are similar to those at the surface, as will be seen from the vertical sections and will be further described below. A casual variation of the wind cannot create a momentary displacement of a deep water-stratum.

Our observations seem to prove that there are many but rather small *variations in salinity due to a heterogeneous or irregular distribution of salinity.* Patches of water with relatively high salinity may evidently alternate with patches of less saline water. These variations are, in many cases, probably connected with peculiar dynamic conditions.

Near the border of a current or, generally, in places with a great horizontal gradient of salinity a persistent departure from the average wind conditions will evoke variations of salinity at a fixed point (relatively to the sea-bottom). Such variations cannot be properly studied by means of our observations (cf. section 7).

7. The Surface Temperature.

The **A**-curves for surface temperature (t_s) on pp. 76*, 78*, 80*, and 82* show clearly the same general variations as we find in the salinity curves. An increase in salinity corresponds to an increase in temperature. The only exception to the rule is that the coastal surface waters in August (the last series) were as warm as, or even warmer than the Atlantic water outside. Near the Newfoundland coast the surface water was also warmer, and at the same time less saline, than further out in the Labrador current. This corresponds to the well known fact that in summer the surface water near a coast is very often warmer than out at sea. This was not the case, however, along our route in British waters on July 27th and 28th.

When the exceptions mentioned are left out of account, a study of the **A**-curves will show that *the variations in salinity coincided with similar variations in temperature.* On the 11th, 12th and 20th of June, not far from the Azores, the surface temperature had a maximum not accompanied by a similar maximum of salinity. Otherwise there is a perfect positive correlation between salinity and temperature as far as these smoothed values are concerned. This correlation will be dealt with generally in section 18.

The great variations in the mean surface temperature in the areas in question are, therefore, due to the regional variations. The smaller variations are more easily recognized in the temperature curves than in the salinity curves (on account of the scale used). They are evidently due to local variations in the direction of the currents or in the track of the ship. A small deviation from the general direction of the current or of the ship may produce a marked effect in places where the horizontal gradients of salinity and of temperature are considerable, as will always be the case when the water flows with great velocity relatively to the surrounding water-masses, *e. g.* near the northern border of the "Gulf Stream" between America and Europe.

The positive correlation between salinity and temperature is very conspicuous even in the details shown by the **B**-curves. With the exception of the series from August, the various series show with remarkable clearness that almost all the rapid variations in salinity were accompanied by quite similar variations in temperature. *The daily period of temperature* is not so evident as might be expected: it is very often entirely blurred by the local variations. It is, therefore, a very unsatisfactory task to determine the daily variations of temperature from observations made on board a ship which passes through heterogeneous water-masses. Reasonably trustworthy results can, as a rule, only be obtained by measurements covering

a long time taken from a ship drifting with the current. Only when the salinity is almost constant will the daily variation of temperature exhibit itself clearly, as may be seen from some parts of our curves. But even then some unexpected variations of temperature may be found (cf. July 23rd to 26th). When we compare the surface temperature (the **B**-curves) with cloudiness (**A**-curves and **B**-curves) we find — as might be expected — that the daily temperature variations were much more prominent with slight than with extensive cloudiness (cf. June 7th—9th, 11th, 19th—22nd with slight cloudiness and a distinct daily period of the surface temperature, while the observations from August demonstrate great cloudiness and scarcely any trace of the daily period).

By means of very extensive material in the form of temperature observations from the sea surface and the air, Professor NANSEN and I have studied the annual and monthly temperature variations in the North Atlantic [HELLAND-HANSEN and NANSEN, 1917, 1920, 1921]. We have found that temperature-variations of this kind in a definite place (relatively to the sea-bottom) appeared at first in the air and afterwards in the sea surface, both of them being due to general alterations in the distribution of air pressure and consequently in the winds. We came to the conclusion that the variations in surface temperature were chiefly the result of a displacement of the surface-layers. The direct warming or cooling effect of the air upon the sea seemed to be of secondary importance. These results agree with the results we have come to above. The temperature of the water without regard to the geographically fixed place is in close correlation with the salinity. The wind only produces a slight thermal effect directly, but it may displace the surface water, with the result that the *variations observed from a fixed point take place in salinity and temperature simultaneously*. This effect is gradual, and may be detected by continuous observations at fixed stations or in the average for small areas, but not by means of observations made along a route which is traversed rather quickly. If temperature variations of this kind were not closely connected with the movements of the water, we might expect to record temperature variations which were quite independent of salinity variations.

It must be borne in mind that the heat capacity per volume is about 3300 times as large for water as for air. An average heating of the air from the sea surface upwards to 300 metres by 1° C will correspond to an average cooling of the uppermost 10 metres of the sea-water by less than 0·01° C. A heating or cooling of the atmosphere from the sea will therefore have only a slight influence upon the latter when it is not continued for a long time.

The wind will, of course, effect a mixing of the upper water-layers owing to the waves. When there is a marked vertical temperature gradient in the upper few metres of water quite appreciable temperature-variations may be observed at the very surface. A maximum of temperature as well as of salinity will mostly be found at the surface or in the surface layer in the North Atlantic in summer. It will, however, be seen from the Tables that the temperature gradient for the upper 10 or even 25 metres was very small, so that a stirring by waves would as a rule have only an insignificant effect on the surface temperature. Generally no long time elapses between the occurrences of fresh winds in the North Atlantic so that no appreciable cumulative effect will be established as far as the vertical differences of temperature are concerned. But some variations of this kind may be expected, and it will also be seen from the **A**-curves that a high wind velocity corresponded to a general, though small, fall in temperature, irrespective of the direction from which the wind was blowing. A small effect may also be traced in the salinity.

8. The Air Temperature.

The **A**-curves for the air temperature (τ_a) are drawn on identically the same scales as the curves for the surface temperature (τ_s). The two curves accompany each other remarkably closely in all series, and the rapid and great variations in both elements coincide much better than might be expected (cf. June 26th to July 2nd, and July 8th to 12th). The curves very clearly reveal the important fact that *the mean air temperature had a strong tendency to follow the mean surface temperature. The difference between the two was, on the average, only very rarely as much as 2° C,* even if the air had come directly from Arctic regions with much lower, or from Tropic regions with much higher temperatures. Our curves, in combination with the synoptic charts, prove that *the air about 5 metres' height above sea level very quickly adopts a temperature approximating to that of the sea surface.*

The greatest differences $(\tau_s-\tau_a)$ of the averages were found in the second series of observations between June 27th and July 1st, in a region with rather abrupt hydrographic variations where there is only a short distance between warm and cold water. But even there the two curves exhibit the same great changes. On June 26th the air was relatively cold in spite of a wind, at times strong, blowing from S, SW, or W. It will be seen from the charts that the air just N of our position on the 27th of June in the morning came from NW with temperatures between 12° and 17° C. On the 28th of June (morning) the wind in places W of our position came from N, while we observed

a westerly wind. There were great changes of wind in this locality, a strongly developed cyclone passing by. It seems to be quite obvious that the air observed by us had come from northerly and not from southerly regions a short time (only some hours) before. In this way the relatively great difference (sea temperature minus air temperature) on June 28th is easily explained. On June 29th and the following two days the air came, according to the charts, from southerly regions, giving everywhere in the neighbourhood a higher temperature in the air than in the sea surface. We had then rather suddenly passed from the warm water of the "Gulf Stream" into the cold Arctic waters. In the chart for June 30th an observation is introduced from a place about 100 naut. miles to the S of the "Michael Sars" position, showing an air temperature of 21° C, sea temperature 18·4° C, and a southerly wind of 4 Beaufort. Our observations were respectively 14.0° C, 12·05° C, S, 5 Beaufort (0—12). Between the two places there was a difference in air temperature of 7° C and in surface temperature of 6·35° C. The air had probably traversed the distance in about 7 hours (velocity 7·5 m.p.s.).

For the third series of observations our **A**-curves (p. 80*) show a great difference of temperature between water and air on July 14th. The synoptic chart for that day shows that the wind in those regions came directly from the area of the cold Labrador Current to the West. Observations from a ship within the latter area gave a higher air temperature (10° C) than sea temperature (7·5° C), while the simultaneous "Michael Sars" observations further east gave 13·6° and 16·2° C. Here, too, the transition from cold to warm water takes place within a short distance; and in such cases relatively great temperature-differences between water and air must be expected. The heating or cooling of the air takes place very quickly though not instantaneously.

By comparing the **A**-curves for sea temperature and air temperature we find confirmation of the well-known rule that the sea surface is generally warmer than the air. Out of all the averages only 32 % show an air temperature higher than the surface temperature, even though the investigations were made in summer when the general rule is often reversed. When we study the details exhibited by the wind curves and vectors and the synoptic charts we find, practically without exception, that the air temperature increased relatively to the sea temperature when the wind came from warmer areas, and decreased when the wind came from colder ones. The increase is particularly marked in cases when the horizontal temperature gradient was comparatively strong, and especially when in addition the wind velocity was great.

We need only take a few cases as examples to show the details. In the third series (**A**-curves p. 80*) we find:

July 9th. Air temperature relatively much higher than sea temperature. Wind from warmer regions.

July 10th. Smaller difference between air temperature and sea temperature, air warmer than sea, wind from warmer regions, but very light.

July 11th. Wind quickly veering from southerly directions (warm) to south-westerly, westerly and north-westerly (cold) with increasing velocities, air temperature quickly decreasing relatively to sea temperature.

July 12th. In the afternoon wind veering to SW (warm), air temperature increasing relatively to sea temperature.

July 13th. In the forenoon increasing wind from warmer regions, air warmer than sea. In the afternoon comparatively fresh wind from colder regions, temperature quickly decreasing and becoming much lower than sea temperature. The cold and fresh wind also prevailed on the following day.

July 15th. Wind from cold areas but with decreasing velocities, air colder than sea but with decreasing differences.

In this way we may follow the variations from day to day and practically everywhere find a clear verification of the following general laws referred to the *24-hour means of temperature:*

The air temperature is in most cases lower than the sea temperature and always when the wind has quite recently come from colder regions. The difference — sea temperature minus air temperature — is then greater with a rapid air-current than with a slow one.

The temperature of the air approaches the sea temperature when the wind has come from warmer regions and becomes higher than that of the sea when the air moves with comparative rapidity.

We shall now consider the more individual and the short-period variations exhibited by the **B**-curves. As stated above, the *surface* temperature, even in the details, coincided with the salinity and the daily period was often indistinct. The detailed variations of the *air* temperature, we find, show a more marked *daily period,* with a maximum in the middle of the day or in the afternoon, and a minimum in the night. But *these daily variations were often greatly modified by local variations of the surface temperature* and might sometimes be entirely blurred. Consequently there is also quite a good correspondence between the **B**-curves for sea temperature and air temperature, and there is even a considerable resemblance between the **B**-curves for salinity and air temperature. In many cases the extremes appear a little earlier in the curves for sea temperature than in those for air temperature, sometimes indicating that the surface conditions were primary. The daily period in the air temperature, with its greater

amplitude, as well as the variations in wind are, however, very often apt to cause displacements in the opposite direction.

Along the same zero-lines and with the same scales as the **B**-curves for air temperature some broken curves for the variations in the difference between sea temperature and air temperature have been drawn. The difference, sea temperature minus air temperature $\left(\tau_s - \tau_a = \triangle\tau\right)$, has been found from the values in Table I b for every second hour, and the 24-hour averages referred to the hours of observation have been calculated $\left(\triangle\tau_{12,2}\right)$. The differences between the individual values and these averages $\left(\triangle\tau - \triangle\tau_{12,2}\right)$ have been smoothed by taking means of 3 values continuously $\left(\left(\triangle\tau - \triangle\tau_{12,2}\right)_3\right)$, and the values found in this way are represented in the broken curves pp. 76*, 78*, 80*, and 82*. Positive values (drawn upwards from the abscissa) mean that the surface temperature was higher than the air temperature, negative values (downwards) that the air was warmer than the sea.

The curves show that the variations in the difference, sea temperature minus air temperature, in the great majority of cases occurred inversely to the variations in air temperature. This means either that the variations in the temperature of sea and air occurred in inverse relation to each other, or that the variations in the air temperature were more prominent than in the sea temperature. Both cases occur, and will mostly be related to a predominant daily period of the air temperature. *The air was as a rule warmer than the sea by day and colder by night,* the broken curves showing in most cases a minimum by day and a maximum by night.

9. Humidity and Fog.

The general features exhibited by the ***A****-curves for the North Atlantic show the same regional distribution of the quantity of water-vapour as of the temperature of the air, and consequently* (sections 7 and 8) *of the surface temperature and salinity as well.* Those regions where the surface salinity and temperature were high had also a high air temperature and a high absolute humidity. Only in the case of coastal waters in summer time may this general correspondence fail, because the temperatures may be high in relation to the salinity (cf. sect. 7) or the air may be dry when it has come from a continent.

The *variations* in the general distribution of air temperature and absolute humidity also corresponded very closely to each other, as will clearly be seen from the curves (see especially the figure representing the third series of observations, p. 80*). For these variations the correspondence with the surface temperature is less pronounced, or even absent. We have seen (sect. 8) that the air temperature sank or rose in comparison with the surface temperature according to the direction of the wind. For the sake of brevity we shall assume that southerly winds are winds which bring the air from warmer to colder regions, and that northerly winds are those which bring the air from colder to warmer regions. In this sense of the words we find that southerly winds gave higher temperature and absolute humidity, and northerly winds made both these elements decrease. The correspondence is especially pronounced when not merely the air temperature but also the difference between the surface temperature and the air temperature is taken into consideration. The absolute humidity was comparatively high when the air was warmer than the sea and low when it was colder, and *the variations in humidity corresponded to the variations in temperature-difference between water and air.* The exceptions to this rule are very rare (in the first and last series of observations only; there are none in the second and third series).

Now it is rather surprising that *the variations in relative humidity demonstrated in our* ***A****-curves generally coincided almost exactly with the variations in absolute humidity.* We can disregard those instances when the air was for some considerable time saturated with humidity, and fog occurred. Otherwise there is almost perfect agreement even in minor details as regards the absolute and relative moisture in the air above the sea. Divergencies in the rate of rise or fall (the derivate) of the average quantities are easily explained by an examination of the wind conditions.

Northerly winds in the sense mentioned above would, when increasing, generally cause an extra decrease in absolute as well as relative humidity (cf. June 7th—10th, 19th, July 11th, 23rd, 25th). On June 28th we had a relatively low air temperature and a very low relative humidity in spite of a southerly wind veering westerly at the time. We have already shown, however, that the same air had in all probability come directly from cold northern regions only a few hours before. The air from northerly regions in the North Atlantic contains a comparatively small amount of moisture, and such "Polar" air appears to be comparatively dry when heated. Similarly, we generally find a comparatively low humidity in continental air moving seawards. On August 12th we experienced a sudden fall of humidity because the wind on that day brought air from Northern Europe. The next day we had an increase of absolute and relative humidity because the wind changed and brought air from a relatively warm part of the Norwegian Sea.

With increasing southerly winds in the North Atlantic we generally find an extra increase of relative humidity (cf. *e. g.* June 24th—26th, 29th, July 13th, 20th, 26th). It must, of course, be borne in mind that our observations only comprise certain parts of the North Atlantic and that we lack observations from some important areas. Our conclusions are therefore limited in regard to locality as well as time. But for those parts of the Ocean that we have investigated in the "Michael Sars" expedition we find that *as far as the averages are concerned* (the **A**-curves) *the variations in relative humidity did upon the whole go parallel to the variations in wind velocity with southerly winds and inversely with northerly winds*, the variations being generally felt earlier in the wind than in the humidity.

In order to explain these conditions we must call attention to the conditions of equilibrium in the lowest part of the troposphere. By vertical movements of the air its temperature varies adiabatically. When the air ascends it becomes cooled by 1° C pr. 100 m. (the "dry adiabatic"), provided that the water-vapour does not condense and liberate its latent heat of evaporation. When the air is perfectly mixed we find below the level of condensation a vertical temperature gradient corresponding to the dry adiabatic. A stronger gradient (a quicker decrease of temperature upwards) means a state of lability, and a smaller gradient a state of stability. As the sea surface is upon the whole warmer than the air, we generally find that the air above the ocean is heated from the under boundary, *i. e.* there is a state of instability in the lowest layer of the troposphere. When the air is stirred by winds it ascends, and up to the height of its ascension it tends to produce a gradient corresponding to the dry adiabatic. This height will, with continuous spells of wind, ultimately become the height of condensation, or at any rate a height above which a smaller gradient (may be inversion) rules. By this ascension the water vapours are carried upwards. The air ascending from the sea surface must be replaced, and the new air coming near the sea surface as a substitute must obviously as a rule have a relatively low humidity when the air is colder than the sea. With a positive temperature gradient in vertical direction (temperature decreasing upwards) the absolute humidity must upon the whole decrease upwards, the more so as the moisture comes from the sea surface. Aerological observations have shown that even the relative humidity very often decreases upwards. As long as the heating from the sea surface takes place the turbulence is apt to provoke a reduction in the absolute humidity observed at quite low heights and an increase at higher levels.

In the case of a labile equilibrium the descending air doubtless reduces the temperature observed, but as long as a heating of the advancing air really takes place the relative humidity must sink, provided that the air (as is generally the case) has not been saturated all through.

Such conditions are especially prevalent with northerly winds in our areas of investigation. With northerly winds, therefore, we may lay down as a general rule that the records of air-temperature give sinking values at the same time as the observed difference of temperature between water and air increases and both the absolute and the relative humidity observed decrease.

With southerly winds (in the sense defined above) the air is cooled from below so that an increasing state of stability is established. The temperature increases from the surface and for some distance upwards, and provided that we have to deal with "old" sea-air and not relatively dry air from the continents or air which has recently come from Arctic regions, the relative humidity will increase. The absolute humidity will *eo ipso* be greater in warm sea-air from the south than in cold air from the north. In a state of pronounced stability the mixing of the air proceeds more slowly upwards than in the case of lability, thus limiting the effect to lower heights. In this manner the increase of absolute and relative humidity is intensified in the lowest air-layer.

In his important memoir on the "Scotia"-observations in 1913 G. I. Taylor [1914] has arrived at some very interesting results, obtained by means of kite and balloon ascents. He studied the "life-history" of the air in which his aerologic observations were made, and found a close correspondence between the path of the air along the sea surface during the preceding days, the surface temperature, and the vertical distribution of air temperature and humidity. How far, and how rapidly the influence of the sea surface and the casual wind will make itself felt upwards depends upon this "life history", because it is the decisive factor governing the variations in the vertical gradients and the state of equilibrium in the lowest part of the troposphere.

In calm weather, the conditions are quite peculiar. When the sea is warmer than the air, this ascends with its content of water vapours, and the evaporation may then go on permanently because new unsaturated air appears at the sea surface. When, on the other hand, the air is warmer than the sea, the state of stability is apt to become more and more prominent. A film of air along the sea surface may become saturated with moisture and fail to ascend on account of its comparatively low temperature. As a result, evaporation will cease. Such a case may easily occur in summer time, especially in the middle of the day. *Under these circumstances the evaporation may have a minimum irrespec-*

tive of a high temperature in water and air [HELLAND-HANSEN 1916].

During the "Michael Sars" Expedition *fog* was met with several times. It is noted in the Tables on June 30th, July 1st, 2nd, 8th to 11th (all of them near Newfoundland), 18th, 26th, and August 7th. The observations of fog are marked in the Figures on pp. 78* and 80* above the **A**-curves, and it will readily be seen, that the fog appeared almost exclusively when the temperature of the air was higher than that of the sea surface. The only exception was on the outskirts of the Labrador Current on the 11th of July for a couple of hours when a northwesterly wind probably brought fog. Evidently *the occurrence of fog is chiefly connected with a prominent stable equilibrium in "old sea-air", i. e. air which has passed over relatively warm parts of the ocean for such a long time that it has attained a high value not only of absolute, but also of relative humidity to a greater height than that reached by the turbulent motion in the place where the fog is formed.* If not, the wind observed on foggy days would dissipate it. In other words, it is not only a question of the difference of temperature between water and air, but also of the vertical distribution of moisture in relation to the actual temperature of the sea surface. The greater the negative temperature gradient and the longer the previous air-path over a warm part of the ocean are, the more favourable will be the conditions for the formation of thick fog. The unusually *great contrast between warm and cold areas* near the Newfoundland Bank is apt to cause unusually thick fogs in this region. In other regions where fog frequently occurs as *e. g.* in the Northern part of the Norwegian Sea (at Spitsbergen etc.) the contrast is much smaller, and we may therefore suppose that the fog in such region is, as a rule, not so dense. It must be remembered that the air may often be supersaturated with water-vapour before the condensation takes place, and the actual conditions for the formation of water-drops (the existence of nuclei) must therefore be considered too. It may be possible that there is a connection between strong wind (much spray giving minute water-drops or salt-particles to the atmosphere) and a subsequent formation of fog. —

We shall now turn to the **B**-curves, demonstrating casual and short periodic variations in humidity. It is evident that even these variations were common to the absolute and the relative humidity in the great majority of cases. This means that the general conclusions arrived at in regard to the averages also hold good in regard to the more detailed variations, within short intervals of time. The correspondence with the variations both in air temperature and in the temperature-difference between water and air is also quite evident; the divergencies may in most cases be explained by the wind-conditions.

In most cases, then, we also find *a maximum of absolute as well as of relative humidity by day and a minimum by night* corresponding to the daily period of the air temperature. There are many exceptions from this rule, but it holds good in the large majority of cases. *In the middle of the day (in summer) the air was mostly warmer than the sea* (cf. sect. 8) *so that a stabile equilibrium was established, with an increase of humidity near the sea surface. At night the reverse was as a rule the case, giving lability with a decrease of humidity near the surface.* Many of the exceptions are easily explained when the various elements are examined in detail.

10. Cloudiness.

The observations of clouds were restricted to an estimation of the extent of the cloudiness, and did not embrace the cloud-forms. It is not possible, therefore, to treat the variations in cloudiness in a satisfactory manner.

In the 3rd series of observations, between the Newfoundland Banks and the British Isles (curve p. 80*), the observations were so scanty and doubtful within the foggy region near Newfoundland that the averages for two or three days could not be calculated. The sea temperature increased on the whole until the 18th of July, as did also, correspondingly, the air temperature; but on a wide average the cloudiness continued to sink until the 17th. Taking the minor variations, however, it is quite obvious that the cloudiness varied with the variations of temperature, and still more with the humidity. An increase of temperature and humidity corresponded to an increase of cloudiness, and a decrease of the various quantities was mutual. There was obviously some retardation of the variations from air temperature to humidity and further to cloudiness.

This parallelism may probably be accounted for by the fact that *temperature and humidity increase with the beginning of southerly winds in front of the depression, and that cloudiness soon increases too on the further approach of the depression.*

The cloudiness in depressions has been explained by the polar front theory of Professor V. BJERKNES and his collaborators. This theory sets out from the fact that the temperature distribution in depressions often exhibits a prominent line of discontinuity forming the boundary between air of polar and tropical origin. This boundary line, the "polar front", corresponds in the free atmosphere to a boundary surface directed obliquely upwards with an inclination from the horizontal of about 1 : 100. All the clouds giving continuous rain (ASt and high Nb) seem

to be formed in the warm air ascending the inclined polar front surface, either during an onset of warm air or of retreating cold air, or during a cold onset forcing the warm air to escape upwards.

Clouds formed in this way cannot be expected to stand in close correlation with the momentary meteorological conditions deep below them at the sea surface. They are the product of a more complex interaction of air masses of different densities brought together from widely distant regions. The clouds lower down have a more direct connection with the conditions at the sea-surface.

The water-vapour absorbed from the sea is transported upwards into the atmosphere when the latter has become unstable by heating from below. The longer and more intense this heating has been, the greater is the amount of moisture in the upper air, and the lower and denser the clouds formed. In the region now discussed the air to a great extent comes from the American Continent or from between Labrador and Greenland being at first cold or cooled, then heated by the "Gulf Stream" water and afterwards making its way northwards again as an air-current which is relatively warm in its lowest part. A detailed survey of the wind-vectors and curves, and of the synoptic charts, shows that the maxima of cloudiness especially appeared in southerly winds which transported air that had first passed the cold parts of the sea and then the warm areas before returning northwards (see *e. g.* July 13th, 21st and 24th).

With northerly winds the air would mostly come directly from the cold regions without having been heated for any length of time. We have previously mentioned that such air must make the observed temperature and humidity sink. At the same time the cloudiness will become relatively small if the cold air dominates up to high altitudes, because the upper air is not sufficiently moist for the formation of thick clouds. As time goes on the cloudiness will probably increase, owing to the instability. This cloudiness, however, which is due to local ascending "currents" through unstable air, gives the typical broken sky with Cu and CuNb and seldom completely overcast heavens for any length of time.

On July 18th the wind was north-westerly in the afternoon, nevertheless the air temperature rose and the humidity increased to such an extent that even a light fog was formed and low clouds covered the sky. The charts for July 18th and 19th show, however, that the air had originally come from W or SW and only made a short visit to the north, keeping a relatively high temperature and probably being very humid for some distance upwards. The fog had probably been formed further to the north.

In our first series of observations, to the south of the Azores (p. 76*), the wind came mostly from between north and east, and the air was essentially in a state of instability. We were within the precincts of the North East Trade winds with their relatively dry air, generally with no great extension of clouds (the scale for cloudiness is larger in this series than in the others). The **A**-curve for cloudiness shows variations which seem to be rather irregular without any definite connection with the variations either of humidity or of wind.

During the fourth series of observations (p. 82*) the sky was overcast nearly all the time except in the neighbourhood of Scotland and Norway. The upper air was probably very moist, having come more or less directly from the Atlantic as "old sea-air".

The divergencies from the daily means demonstrated by the **B**-curves correspond in most cases to the variations in wind velocity. It should be remembered that the wind direction, and not only the velocity, may vary at the level of the clouds as compared with the stratum at the sea surface. Full agreement, therefore, cannot be expected. An increase of wind, however, especially along our route from America to Europe, meant in the majority of cases the proximity of depressions, and therefore great cloudiness. An increase in wind velocity may often cause an alteration in the state of equilibrium. We accordingly find, that the variations in wind-velocity and cloudiness exhibited by the **B**-curves generally went nearly parallel when there were "northerly" winds (*e. g.* June 6th to 12th), while with "southerly" winds (*e. g.* June 22nd to 25th) the variations were liable to be reversed.

The variations were sometimes apparent earlier in the cloudiness than in the wind. This is partly due to the fact that the wind-velocity may be much greater at the cloud level than at the surface, and partly to the fact that the estimation of the cloudiness embraces wider areas.

11. The Interaction of the Ocean and the Atmosphere.

The observations dealt with here were made in June—August 1910 only, and were locally restricted to some few lines. The results set forth above are therefore, strictly speaking, very limited in regard to time and locality. They seem, however, to give a fairly systematic and clear view of processes taking place between the sea and the atmosphere, so they probably possess a more general application, all the more so because they coincide in many respects with results already known. We proceed to give a general review of these processes, along the lines of the detailed discussion in the previous sections.

To begin with we may lay down following propositions:

The conditions in the atmosphere have a dynamical and a thermal effect upon the ocean. Dynamically, the essential direct effect is the creation of wind-currents, and of convection currents due to local variations of precipitation and evaporation. The wind pushes the surface water forwards, generally in a direction *cum sole* from the direction of the wind. The water is displaced from its normal position by variations of the wind, and such displacements may be recognized in annual or monthly averages from fixed geographical areas. The geographical variations of precipitation and evaporation on the one hand and of temperature on the other will, upon the whole, give a certain positive correlation between temperature and salinity. In the North Atlantic these quantities as a general rule increase or decrease simultaneously (cf. section 18). We shall mostly find that the isohalines and the isotherms, even at the surface, go parallel, and that a close agreement between the variations in salinity and temperature is established.

The thermal effect of the atmosphere upon the sea is chiefly of two kinds: indirectly by the variations in transparency which will evoke variations in the quantity of solar radiation absorbed by the sea and of radiation from the sea, and directly by the heating or cooling effect of the air by its contact with the water. Investigations have shown that, on an average, 2/3 of the solar radiation penetrating into the atmosphere is absorbed by the latter, while the rest reaches the sea or the solid crust of the earth. The solar radiation is subject to variations, as is also the quantities of solar radiation absorbed by the atmosphere in proportion to the total radiation. The variations in atmospheric absorption create variations in air pressure and winds, and thereby indirectly affect the ocean currents. The variations in oceanic absorption affect the temperature of the sea directly and give rise to various hydrographic variations (thermally and dynamically). The direct thermal effect of the atmosphere upon the sea, due to contact between the two elements, is but small when observed for a brief period, but the cumulative effect may be rather substantial, especially as regards the cooling in winter.

The sea must, on the other hand, exercise a powerful influence upon the atmosphere. The air at the sea surface very quickly adopts a temperature which is near that of the sea. The consequence is that the air temperature above the ocean will show on an average much the same distribution as the surface temperature. The comparatively slight differences of temperature between water and air are however of the utmost importance to the atmospheric processes. A positive difference (sea temperature minus air temperature) means a state of instability whereby the heat as well as the moisture will be propagated upwards into the atmosphere. This process is highly intensified by turbulence, and the amount of heat or moisture carried to distant regions and released there depends to a great extent upon the wind velocity, as well as upon the value of the temperature difference. In the state of instability the total amount of moisture (or the evaporation from the sea) tends to increase, although the humidity measured on board a ship may show a decrease, at any rate to begin with, under ordinary circumstances. A negative difference of sea temperature minus air temperature means stability. The cooling of the atmosphere will not be propagated as quickly upwards as the heating in the former case. It is limited to a thinner stratum, in the lower part of which the relative humidity rises, ultimately with the effect that the evaporation decreases, or even comes to a stand-still. The cooling of the air from the under surface will, therefore, quantitatively have little effect upon the atmosphere in comparison with the heating. As the sea-surface in most regions and during the greater part of the year is warmer than the air, the levelling influence of the sea upon the climate must be a levelling "upwards" as far as temperature and precipitation are concerned: the sea gives on an average a higher temperature (not only a smaller amplitude) and a greater precipitation.

One consequence of the above conclusions is that there is an intimate connection between the surface salinity, the surface temperature, the air temperature, the humidity, and even to some extent the cloudiness. The relations between these various elements are modified by the variations in wind, which (at least to a great extent) means the variations in solar activity and in the absorption-conditions of the troposphere.

The atmospheric conditions tend to be relatively uniform above an oceanic region with but slight differences in temperature. Places where abrupt hydrographic changes exist, however, are the scene of many and rapid meteorological variations. Such a region is found along the northern border of the "Gulf Stream" across the Atlantic. Even short displacements of the air may here create pronounced stability or pronounced instability with corresponding variations in heating effect, evaporation and cloudiness. It is especially important that a comparatively high degree of instability is often evoked by "Polar" air coming into the "Gulf Stream" area. A great deal of water vapour will thereby come into the atmosphere. When more than ordinary quantities of such "Polar" air move across the warm areas of the North Atlantic and proceed to Northern Europe we may expect to find, on the average, in the latter region a surplus of rainfall with a reduced annual amplitude of air temperature; possibly this

effect will be even more marked than in the case of constant flow of "Equatorial" air, because this would have been subject to continual cooling and therefore be in a state of stability. In the latter case, however, an encounter with "Polar" air would give a vertical component upwards, with a resulting condensation and rainfall.

In view of what has been said above it seems very desirable to establish closer and more general co-operation between physical oceanography and meteorology than has hitherto existed.[1])

III. SUB-SURFACE TEMPERATURES, SALINITIES, and DENSITIES (METHODS).

12. The Temperature Observations.

In by far the greater number of cases the sub-surface temperatures were observed by means of reversing thermometers obtained from C. Richter in Berlin. The thermometers were carefully tested, and new determinations of the zero-point were made on April 9th. Almost without exception the best thermometers worked excellently. In one of the water-bottles the same two thermometers where used simultaneously 517 times. The difference between the corrected temperatures was

0	in	179	cases
0·01°	„	228	„
0·02°	„	86	„
0·03°	„	20	„
above 0·03°	„	4	„

The average difference was less than 0·01° and the mean error about $\pm$ 0·005° C.

The determinations with each thermometer are stated separately in Table II. The thermometers were always allowed 3 minutes or more at the depths of observation before they were reversed. The thermometers were read by means of a magnifying lens [cf. Helland-Hansen, 1912, for further particulars as to the reading and correction of the thermometers].

Pettersson-Nansen's insulating water-bottle was used at some stations, *viz*:

Stat. 10, 183 metres (the first observation, at 14^h 41^m) 274 m, 640 m. (the second observation, at 15^h 50^m), 914 m. (the first observation, at 14^h 11^m), and 1372 m.
„ 10 A, 1829 metres.
„ 91, 4750 „
„ 97 — 116 (incl.), for all sub-surface observations.

In these cases a Nansen-thermometer, fixed tightly in the lid of the water-bottle, was used for the temperature-determinations, generally together with a reversing thermometer placed in a special frame on the water-bottle. The readings of the Nansen-thermometers were corrected for the adiabatic cooling of the water-sample and the water-bottle as well as for instrumental error. The corrected temperatures recorded by the Nansen-thermometer are marked with an asterisk in Table II, in the case of Stations 97 — 116. In the case of the other stations mentioned above, the asterisk was inadvertently omitted when printing the Tables. Where a determination with a reversing thermometer was also made, the temperature is printed in the Tables below that recorded by the Nansen-thermometer.

The same Nansen-thermometer (made by Müller in Ilmenau) was always used in the Pettersson-Nansen water-bottle. By determinations of the zero-point on April 9th the reading in pure melting ice was —0·027° C, and the relative corrections for other parts of the scale were known from earlier determinations. When the thermometer was used at Stat. 10 it was observed that a small drop of mercury had detached itself and come into the upper enlargement of the thermometer. It could not be brought back again by simple means available on board. When the thermometer was used afterwards, it was observed that the small drop apparently remained constant. After the return of the Expedition to Bergen it was found that the reading of the thermometer in pure melting ice was —0·09° C, the drop thus corresponding to 0·06°.

[1]) During the "Armauer Hansen" Expedition to the eastern part of the North Atlantic in the summer of 1922 very extensive meteorological material was collected in close connection with hydrographical observations. This work was to a great extent inspired by the results of the "Michael Sars" Expedition.

13. The Water-Bottles.

For collecting water-samples from beneath the surface EKMAN's reversing water-bottle, PETTERSSON-NANSEN's insulating water-bottle, and NANSEN's automatic water-bottle were used.

EKMAN's water-bottle was used in by far the greater number of cases from the beginning of the cruise until July 27th (Stat. 96). The exceptions at Stats. 10, 10 A, and 91 have been mentioned in the preceding section. Descriptions and illustrations of the instrument will be found in papers by EKMAN [1905] and HELLAND-HANSEN [1912], and we shall here only mention the following. The water-bottle consists of a brass cylinder pivoted on an axis in a metallic frame. The lids at the ends of the cylinder are closed or opened as the cylinder turns, by two pairs of eccentric rods. When closed the cylinder is caught and held by a hook. During the "Michael Sars" Expedition it sometimes happened that the hook did not catch, because the eccentric rods had become somewhat bent, or the rubber plates on the lids were a little out of position. A note was always made in the journals when this happened. By the titrations made at Gibraltar it was proved that the water-samples in such cases were quite worthless, the salinity found being that of the water near the surface. Afterwards no samples were drawn when the water-bottle was not perfectly closed. We had two sizes of the EKMAN water-bottle. The larger one was almost always used until it was lost by an accident at Stat. 88.

The smaller one was used for some few observations before this station, and for Stats. 88—96. At Stat. 96 the tube for the reversing thermometer was lost. The water-bottle was, therefore, not used for the later observations. The EKMAN water-bottles were constructed for use in series with two or more on the line simultaneously. On the "Michael Sars" Expedition, however, we used only one at a time, except at some few stations, because it was found that two apparatus together did not work quite satisfactorily in our case.

A description of the PETTERSSON-NANSEN water-bottle will be found *e. g.* in publications by NANSEN [1901], EKMAN [1905] and HELLAND-HANSEN [1912]. It was used at Stats. 10, 10 A, 91, 97—116, (cf. sect. 12).

NANSEN's automatic water-bottle [EKMAN 1905, HELLAND-HANSEN 1912] was only used at Stat. 13 when the ship lay still. The depths of observation were measured by the meter-wheel, and compared with the indications of the bathymeter in the water-bottle. As this bathymeter proved not to work satisfactorily the water-bottle could not be used when the ship was moving.

EKMAN's and PETTERSSON-NANSEN's water-bottles were operated by means of messengers. From a number of experiments it was found that our messengers fell along the line at a speed of about 4 m. per second. In the journals the time when the messenger was sent off was always noted.

14. The Water-Samples and Their Treatment (Titration).

The water-samples were mostly collected in glass-bottles with a patent stopper. During the latter part of the investigations we had no more bottles of this kind left, and had to use ordinary medicine bottles of 150 to 250 cc. volume with cork-stoppers for some of the surface-samples collected in the last days of July, and for all samples collected in August (*i. a.* Stats. 97—116). Shortly after such a bottle was filled, the stopper and the neck of the bottle were carefully covered with paraffin wax in order to prevent evaporation from the sample.

The water-samples were titrated in the way described in "The Ocean Waters" [HELLAND-HANSEN, 1912].

Bulb-burettes were used. Some of them were specially made for the Expedition with a division from 18·5 to 22 corresponding to the high values of chlorinity found in many of the waters to be examined. The unit of division embraced 2 cc. and the readings could easily be exact within 0·005 units. Titrations of the samples from the first part of the cruise, until Stat. 17, were made ashore in Gibraltar when the "Michael Sars" visited that harbour. The samples from the subsequent stations up to Stat. 34 were examined in La Luz (Gran Canaria) 18—21 May, 1910. All other water-samples were titrated in Bergen during the following autumn-and winter-months. By far the larger number of samples from serial observations at stations and a number of the surface-samples were examined twice or more, some of them even 5 or 6 times. All samples were titrated by the author of the present paper; the second titrations were to a great extent made by MR. I. C. GRØNDAHL. The mean error for the sub-surface samples hardly exceeds 0·01 ‰ of salinity.

15. Time. Depths of Observations.

The direct results of the serial observations will be found in Table II (pp. 21*—33*) where the first column contains the time when the water-bottle was actually closed or the thermometer reversed at the depth of observation. The time is given as local mean time (L. M. T.), being converted from the ships's time (S. T.) which has been

used for the surface-observations in Table I. Surface-observations belonging to vertical series are entered in both tables, but the times recorded are not identical.

The next two columns of Table II give the depth of observation in metres (m) and English fathoms (f). Time did not permit us to test the meter-wheels before the Expedition started. Towards the end of the cruise, however, the meter-wheels that had been used were carefully tested. It was then discovered that all of them were correct except one, which unfortunately was just the wheel mostly used for the hydrographic work. The correction amounted to about 8·5 %, and the indication had to be reduced by this amount in order to give the correct length of wire let out. This means that a reading of *e. g.* 200 m. corresponds to a length of 183 m. or 100 English fathoms. In all cases where this meter-wheel has been used, we have corrected the readings by taking half the reading as the actual length of wire in English fathoms and converting this length into metres. The final error will not amount to as much as 1 % of the depth provided that the line hung vertically. Much attention was paid to the attaining of a vertical position by the wire. We succeeded practically always in avoiding any deflection of the wire exceeding 10° from the plumb-line when working with the water-bottle, as the "Michael Sars" could fairly easily be manoeuvred and brought to the right bearing and speed in relation to wind and current.

16. Standard Depths.

Owing to the above-mentioned defect in the meter-wheel the depths of observation are in most cases unsuitable. For comparison with other observations and for the discussion of the results it is very useful to have the various data referred to certain integer-numbers of metres. Which depths ought to be selected, depends upon the vertical variations. For the North Atlantic as well as for oceanic regions generally it is desirable that the data should be related to the following depths: Surface, 10, 25, 50, 75, 100, 150 metres; every 100 metres from 200 to 1000 m.; every 200 from 1000 to 2000 m.; 2500 m., 3000 m. and for greater depths every 1000 m. These depths will be called *standard depths* [cf. BJERKNES, 1910, p. 6]. When taking observations at these depths the vertical variations will in all probability be represented with sufficient accuracy. In coastal waters or in other conditions in which the variations in the upper strata (as *e. g.* within the Polar currents) are comparatively large, it may be desirable to have smaller intervals of depth for the upper 100 metres; in such cases the data ought to be stated for every 10th meter down to 100 metres, in many cases also for 5 metres below the surface. For our observations from the "Michael Sars" Expedition the former series of standard depths will suffice in by far the largest number of cases. Within the precincts of the Labrador current the vertical variations may be very great. They will be seen from the station curves and the vertical sections. The observations have been converted into data for the above mentioned standard depths by graphical interpolations and the new values found are published in Table III.

In general, it would be an advantage to have data recorded for these standard depths in hydrographical tables.

17. Graphical Interpolations.

For the interpolations for standard depths the serial observations from all the "Michael Sars" stations have been plotted out on mm-paper, with the depths along the ordinate and temperature, salinity and density along the abscissa. 1 mm on the paper represented 5 m. of depth, 0·05° C., 0·01 ‰ of salinity, and 0·01 σ_t.

When 2 out of the 3 quantities, temperature, salinity and density, are known, the third can be computed. The 3 curves must, therefore, correspond at all points in such a way that any one curve is determined by the two others.

It is necessary to check the result by the graphical interpolation. For instance, we must make sure that the density found from the density-curve is exactly the density defined by the salinity and temperature found from the other curves. In many—probably in most—cases it will be found that the demand for adequacy is not fulfilled by the first drawing of the curves, though the errors will be small and easily corrected when rather numerous points are given from observations both of temperature and of salinity. If there is a great difference in depth between the observations it is more difficult to attain adequacy.

The water-layers within a comparatively uniform region of the ocean generally exhibit a density-curve of definite and almost constant shape. The station curves on pp. 65*—72* show many examples of this. If, then, the temperature observations are so numerous that the temperature-curve can be constructed with sufficient accuracy, any missing salinities may be found in a fairly trustworthy manner by means of this temperature-curve and the probable density-curve. If there are but few observations of temperature and salinity it is impossible to arrive at a satisfactory result unless the general characteristics of the water-layers are known from other stations within the same region. In that case the final results may be quite good, but the mutual checking and correction of the curves will take considerable time [cf. HELLAND-HANSEN, 1916].

The following examples may be given. At Stat. 25 B a temperature-observation was made at 800 m., but no determination of salinity. The curves will be found on p. 66*. The density-curve and the temperature-curve are probably correct. The salinity-curve was constructed in correspondence with these curves, in the way shown by the continuous line in the figure, showing two secondary maxima, at about 800 m. and at a little less than 1 200 m. The broken curve is drawn as it would have been without regard to the other two curves. The difference between the two salinity-curves is quite significant, the greatest difference corresponding to about 0·08 ‰. — At Stat. 68 (p. 71*) we have temperature observations but no salinities at 457 and 549 m. The temperature-curve seems to be well defined and does not leave room for any doubt. This station should especially be compared with Stat. 65. A comparison between the two stations, and the fact that in these regions — as in most parts of the ocean — a temperature-curve and a density-curve generally show similar variations, renders it highly probable that the density-curve should have a form such as that shown in the figure. It follows that the salinity-curve for depths between 300 and 600 m. must be drawn in quite a different manner than what it would be if drawn solely from the few observations of salinity, the maximum difference representing about 0·20‰.

All the serial observations from the "Michael Sars" Expedition have been treated in this way by the interpolation for standard depths, and it is not probable that any considerable errors exist in the values of temperature and salinity published in Table III. The errors are certainly quite minute as far as densities are concerned. This is due to two facts: the densities (without compression) are practically always increasing, or constant, everywhere from the surface downward to the bottom of the sea, even though there may be considerable variations in temperature and salinity; — and the density-curve usually has a comparatively regular form with only small differences in "constructive" details within the same region of the ocean. This holds good also for the other data in Table III: stability, pressure, etc., as they depend essentially upon the densities.

18. Correlation between Temperature and Salinity (Salinity-Anomaly).

Mention was made above (sect. 7) of the fact that, upon the whole, a certain positive correlation exists between temperature and salinity in the surface waters of the North Atlantic. High salinity is generally connected with a high temperature, and low salinity with a low temperature. The salinity variations are chiefly due to variations in the difference between evaporation and direct or indirect precipitation. The variations in temperature are essentially due to the difference between heat absorption and radiation. Even if heat is consumed by evaporation, the correlation mentioned indicates that in the North Atlantic the heat absorption is generally in excess where the evaporation is predominant. There are, of course, many exceptions to the general rule as far as the surface waters are concerned. Thus we often find that the diluted surface water near the coasts is comparatively warm in summer, so that much the same temperature may be met with in water of widely different salinity. The seasonal variations are generally greater in temperature than in salinity, so that the correlation will alter with the season as far as the surface is concerned.

In spite, however, of the manifold variations in the climatological conditions we shall find the above-mentioned correlation rather distinctly shown when we plot out on millimeter-paper the corresponding values of temperature and salinity. This has been done for the surface-observations of the "Michael Sars" Expedition in the North Atlantic proper, with the result shown in the figure on p. 73*. In this figure the following marks have been used: a recumbent cross (×) for the observations between the English Channel and Gibraltar, a ring for those between Spain and the Canary Islands, a triangle for observations along the route from the Canary Islands to the Azores, a standing cross (+) for those between the Azores and Newfoundland, and, finally, a black dot indicates that the observation has been made on the route from Newfoundland to the British Isles. It will be seen that the marks have quite a distinct distribution, which is especially the case within the separate groups for limited locality and time.

The variations in temperature and concentration of the water are predominantly started from the sea surface. Of especial importance are the vertical convection "currents" in winter, which may proceed far downwards in homohaline waters. The effect on the temperature will upon the whole be inversely proportional to the depth reached by the vertical convection "current". The conduction of heat from above in summer is very slow. At a depth of some few hundred metres the seasonal variations are, therefore, quite insignificant. In general, they may be ignored at 200 metres and deeper (cf. chapter VI).

The intermediate and the deep waters are very conservative as to their physical properties. Practically speaking they are only altered by mixing processes. Where very different currents meet and mix the alterations may, of course, be considerable, as *e. g.* in the sea W. of the Gibraltar Strait where deep water from the Mediterranean is poured into the water-masses of the

North Atlantic. The former water has an extraordinarily high salinity (above 38 ‰) because the evaporation in the Mediterranean is in great excess compared with the dilution by river-water and rain, while the temperature is only about 13° C due to the winter-cooling of the surface (in the Ægean Sea). At this temperature the Atlantic water would have a salinity below 36 ‰. The heavy water from the Mediterranean sinks in the Atlantic, while strong mixing processes take place, resulting in mixed water with a high salinity as compared with the temperature. Such variations occur, and we cannot, therefore, expect to find an invariable ratio between salinity and temperature in sub-surface waters.

The figure on page 75* shows the mutual values of temperature and salinity found by all observations from the "Michael Sars"-Expedition, at 20 metres below the surface and downwards. Various marks have been used according to depth and locality. As to depth the grouping has been 20—500, 501—1500, and below 1500 metres. As to locality the following groups have been formed: 1) observations from the English Channel and the Bay of Biscay, and along the coast of Portugal (Stats. 1—17), 2) from Spain southwards, off the coast of Marocco, as far as 26° N lat. (Stats. 20—40), 3) from the Canary Islands westwards to the Sargasso Sea and thence to the Azores (Stats. 44—58), 4) from the Azores along the route of the "Michael Sars" (cf. chart p. 63*) in the western parth of the North Atlantic as far as Stat. 87 above the central ridge (Stats. 59—87), and finally 5) from the latter place north-eastwards towards Ireland (Stats. 88—96). The fourth group (Stats. 59—87) comprises the observations from the western part of the North Atlantic, while the other four embrace observations from the eastern part only.

It is noteworthy that the marks for the sub-surface observations are chiefly crowded within a relatively narrow zone with an even, slightly curved direction. A distinct deviation will be seen for temperatures about 10—11°, the salinities connected with these temperatures being exceptionally high in intermediate water off Spain, Portugal and Marocco. This is a sign of the influence of the Mediterranean in the sense mentioned.

On the basis of our observations from the summer of 1910 I have tried to draw a line representing the average relation between temperature and salinity in the "ordinary" North Atlantic waters. This line will be seen in the figure on p. 75*. In the original drawing a more specialized marking of the mutual values was worked out. In drawing the line special attention was paid to the waters of the western and central parts of the North Atlantic where the influence of the Mediterranean or of the Labrador current was mitigated. The conditions in the upper 100 metres were mostly neglected. A study of the figure p. 75* will show that the marks on the upper side of the line (relatively high salinities) for the most part represent those regions where the influence of the Mediterranean is chiefly felt.

The average correlation between temperature and salinity in the North Atlantic as found by us in 1910, represented by the "normal" line, cannot be expressed by a simple formula for the whole interval between 2° and 20° C. A calculation by means of the method of least squares has resulted in the following formula for the interval between 5 and 15° C.

$$S_t = 34{\cdot}737 + 0{\cdot}038\,t + 0.0029\,t^2$$

This formula will nowhere within the interval give a greater deviation than 0·01 ‰ from the value found from the curve.

A variation of 1° C intermediately in the North Atlantic will on an average be connected with a variation of salinity to such an extent that the density will vary by about 0·1 in σ_t. An increase of temperature generally means an increase of salinity and a decrease of density.

The "normal" temperature-salinity curve is reproduced on p. 74* in such a way that the corresponding values of temperature and salinity can easily be read off. When the value of salinity, found from this diagram for some temperature observed, is subtracted from the observed value of salinity we get a value which may be termed salinity-anomaly. It is most conveniently expressed in $^1/_{100}$ ‰ of S, and may be termed $\triangle$ S (= 100 $(S-S_t)$).

The salinity-anomaly defined in this way is not an explicit expression of the variations. A high (positive) value means either a concentration of the water above the normal, or a cooling below the normal, or both. A low (negative) value represents either an abnormal dilution, or heating, or both. When the calculation of the salinity-anomaly is extended to the upper water-layers we find relatively high values in winter, as well as at most times in regions with an excess evaporation, and we find low values at or near the surface in summer on account of the heating as well as after a relatively large supply of fresh-water from rivers.

In spite of this ambiguity the salinity-anomaly will, however, often give valuable results in regard to the origin and evolution of the water-masses, as will be shown later on. As it is a combined expression of both temperature and salinity, irrespective of the absolute values of those quantities as well as of the densities, it may give numerical values which are useful for revealing conditions not easily found by the ordinary methods [cf. Helland-Hansen, 1916]. It may also be possible to study long-period temperature variations by starting from the salinities observed and calculating "temperature anomalies" (chapter VI).

IV. LOCAL VARIATIONS IN GENERAL.

19. Variations limiting the Validity of Oceanographical Observations.

A question of great importance is, whether or not it is allowable to attribute a general and extended representative value to serial observations from a single station. Variations occur in the sea which restrict the validity of serial observations to the exact time and locality of the measurements. Although it is a problem which is encountered in most cases when observations of temperature and salinity are to be discussed it is as yet very far from being solved. In the oceanographical literature far-reaching conclusions are sometimes drawn from single series of measurements although a short displacement in locality, or observations at another time, might have given quite different results.

It is a well known fact that the deep-water (the "bottom water") forming the greater part of the water-masses in the Ocean is remarkably constant in its physical properties. The local and temporal variations are essentially restricted to the upper water-layers above some 2000 metres below the sea surface, and are in many regions displayed only in the strata much nearer to the surface. Temperature, salinity and density of the upper water-layers as observed from a point fixed relative to the sea-bottom are not only subject to seasonal and annual changes in a variable degree, but in many places evidently also to rapid changes, within some hours or days. The question of these *temporal* variations forms an interesting problem in itself, but may also be of importance to an ordinary geographical study of the distribution of temperature, salinity and currents. In the latter case the importance depends upon the local variations in the physical properties of the water-masses.

It has previously been a common idea that the horizontal variations in temperature, salinity and density at a certain moment have been fairly evenly graded over relatively wide stretches in the great oceans except at some few places, as for instance along the border of the "Gulf Stream" near the coast of the U. S. A. and the Newfoundland banks. This view of the conditions was quite reasonable as long as the observations were scattered over large areas, with long distances between the stations of observation and, consequently, with interpolations for wide gaps. As, however, the number of observations has increased and a dense net of stations has been worked from some deep-sea areas, it has proved that the variations in the physical properties and in the movements of the water-layers on the top of the deep-water are often much greater than was previously assumed. In many regions the conditions are often much more "irregular" than they at first seemed to be. Relatively short displacements of the waters may often occasion quite different results with regard to the distribution of temperature, salinity and other elements of observation. A small variation in the position of the stations may then also lead to mistakes as to the oceanographical changes. It is, therefore, necessary to examine the *local* variations in the sea before we proceed to a discussion of the temporal variations.

20. Local Variations.

At some distance from the continents the *vertical* variations in temperature, salinity and density from the sea-surface down to considerable depths are generally very small in winter. In summer the heating at the surface causes great variations in temperature and density down to some 50 or 100 metres. Further downwards the variations are mostly smaller. They may in some regions show a marked increase again in the lower water-strata on approaching the uniform deep-water. The isotherms and isopycnals exhibit in summer a "step", so to speak, a little below the surface, and sometimes another one, but less pronounced, some distance further down (see for instance Stats. 65 and 68, pp. 70* and 71*). The lower "step" is also found in the isohalines. In coastal waters the salinity is often relatively low in the uppermost layers so that great vertical variations in salinity and density may occur all the year round. This is also the case in those regions where Polar currents are met with, as for instance at the Newfoundland Bank (cf. Stats. 70—74, p. 71*).

We have seen (section 18) that there is upon the whole a marked parallelism between temperatures and salinities. This means that the isotherms and isohalines have much the same course, which is also more or less parallel to the course of the isopycnals. In the eastern part of the North Atlantic some irregularities are caused by the water coming from the Mediterranean. Here the temperatures and salinities at intermediate depths exhibit considerable vertical variations which differ from those in other regions, while the density-variations show no similar peculiarities (see for instance the curves for Stats. 23 and 25 B, p. 66*). Disregarding such irregularities it may be stated as a

general rule that the lifting of a water-layer will demonstrate itself by sinking temperatures and salinities and rising densities when the observations are made at a fixed depth below the surface, while the sinking of a water-layer will cause opposite variations in the observed values of t, S and σ_t.

Layers with great vertical variations are generally called discontinuity layers. Although the conduction of heat (conduction by turbulence disregarded) and the diffusion of salt are exceedingly slow, it is probable that no real discontinuity ever exists in the open ocean. The variations do not take place in jumps, but continuously, however at a very variable rate. This makes an exact treatment of many important problems difficult, or even impossible. For a study of some of the temporal variations it is necessary to study the rate of variation vertically. For the question of vertical oscillations and boundary waves it is of special interest to examine the variations in stability.

We shall enter upon a closer discussion of the stability in a later chapter, and now only refer to the numerical values of this quantity given in Table III. A negative value means a state of lability, 0 indifferent equilibrium, and a positive value a state of stability. $10^8 E = 1000$ corresponds nearly to a variation of 0·01 of σ_t per metre. This is a relatively large variation in the ocean, and when we obtain values of 10^8 E amounting to some thousands we have to deal with such water-layers as are generally called "discontinuity-layers". From Table III we see that the stability is especially large within the region of the Newfoundland Bank at depths between 25 and 50 metres below the surface, but it is also very considerable (10^8 E above 2000) at some small depths below the surface in the sea west of the Azores (Stat. 60, 50—75 m., Stat. 63, 10—25 m., Stat. 65, 50—75 m., Stat. 66, 0—50 m.), in the eastern part of our northern route between the Atlantic Longitudinal Ridge and Europe where the observations were made in July (Stats. 87 to 97 incl., especially between 25 and 50 metres below the surface), and at some stations in the Rockall Channel and the Faeroe-Shetland Channel. The conditions at Stat. 115 in the Faeroe-Shetland Channel will be specially discussed in the following chapter.

When we combine all those consecutive points which have the same temperature we get an isothermal surface. We may construct a number of such surfaces, for instance for every degree or every tenth degree centigrade. Similarly we may construct isohaline surfaces combining points where the same salinity exists, or isopycnal surfaces combining points with the same density. In the latter case we shall now disregard the compression and deal only with the ordinary σ_t-values. When the units are taken sufficiently small, the vertical distance between two successive surfaces of the same kind will vary. In "discontinuity-layers" they come close upon each other, while for instance in the deep-water the distance may be comparatively very large.

These surfaces are generally not horizontal, but are more or less sloping or may exhibit swellings or depressions. The deviations from the horizontal may be due to currents or to undulations caused by internal waves or seiches. In any case such deviations mean more or less considerable *horizontal* variations of temperature, salinity and density in the sea.

A convection current will cause a sloping of the isopycnal and, consequently, of the isothermal and isohaline surfaces. We shall go further into this subject later on, and here only mention that, in the Northern Hemisphere, these surfaces will be elevated on the left hand side of a convection current so that here the water will appear to be comparatively heavy, while the surfaces will be pressed down and lighter water be found on the right hand side, provided that the velocity of the current decreases downwards as is generally the case. The effect is directly proportional to the vertical variations of the current velocities. A convection current with a rapid decrease of velocity downwards manifests itself by a comparatively dense series of sloping isopycnal surfaces, and consequently also by relatively large horizontal variations in a direction transverse to the current. The slope of the isopycnal (and isothermal) surfaces may amount to 1:100 or even more.

It is obviously a common idea that the great currents are rather broad, which would mean that the isopycnals are sloping for a correspondingly great horizontal distance. Recent investigations tend, however, to show that at any rate some convection currents are much narrower than has previously been assumed, corresponding to a sloping of the isopycnals which is steeper, but at the same time narrower in horizontal direction. We have of late made numerous and very detailed investigations of the Atlantic Current in the Faeroe-Shetland Channel and the southern part of the Norwegian Sea. In some cases stations were worked at much closer intervals than has previously been done, namely every 3 to 10 miles. It proved that in the Faeroe-Shetland Channel at places where the velocity of the Atlantic Current was great, the inclination of the isopycnals might be limited to the space between two neighbouring stations, thus giving a much steeper and narrower inclination than would have been found if the distance between the stations had been for instance 20 miles, which would generally have been considered a short distance. We have arrived at similar results with regard to the Atlantic Current in the southern part of the Norwegian Sea (north of Shetland) as also further to the north off the coast of Norway. This indicates that *a strong current may be very narrow, and that very considerable*

horizontal variations in salinity and temperature may take place within astonishingly short distances. There are strong indications that also the Great Atlantic Current off the coast of North America and across the Ocean towards Europe, with its chief branches, is narrower than has hitherto been assumed, the mere surface current being excepted. The main Polar Currents along the east coast of Greenland and off Newfoundland seem likewise to have a great velocity only within a very narrow belt, which upon the whole is confined to a stretch just outside the edge of the continental slope.

In the "Michael Sars" Expedition we crossed the Great Atlantic Current near America south of the Newfoundland banks and east of the Flemish Cap. The distribution of temperature and salinity is illustrated by the sections pp. 91* (the lower section), 92* and 93*. The physical and dynamical conditions in this area will be discussed later on in this paper, and we shall here only draw attention to some features connected with what has been said above. The sections just mentioned show very steep inclinations of isohalines and isotherms. The distance from one station to the next within the area in question is between 90 and 250 kilometres, being so great that important variations may have escaped observation, or that the inclination may have been considerably steeper than shown in the sections. We shall here consider especially the last section, from the Flemish Cap eastwards (p. 93*). Stat. 81 was worked in the forenoon, July 12th. After some hours of tow-netting the observations were repeated at several depths, the new series being numbered 81 A. As far as it can be made out, the horizontal distance between the two series was only 10—12 kilometres, but the vertical distribution of temperature, salinity and density was very different. At Stat. 81 we observed at 549 metres 9·46° C, 35·16‰ of salinity, and $\sigma_t = 27{\cdot}19$. At Stat. 81 A much the same values were found at 457 metres (9·45° C, 35·14‰, $\sigma_t = 27{\cdot}18$). Allowing for small errors in the determinations of salinity we may safely say that the water found at 549 metres in the first series of observations was situated nearly 90 metres higher in the last series. There is a possibility that these variations may be due to vertical oscillations, but such an explication is not at all likely to be the right one. Both series have been used for the construction of the isohalines and isotherms in the section, with the result that a steep inclination of the curves appears at this place. It is, now, interesting to notice that the shape of the curves thus obtained fits remarkably well with the surface observations on both sides of Stats. 81—81 A. Between Stat. 80 and Stat. 81 we met with a maximum of temperature at the surface corresponding to the downward bend of the curves in the section. East of Stat. 81 A we encountered a minimum of surface temperature corresponding to the convexity of the curves in the section. In this case we may corroborate the surface observations with vertical series and obtain a somewhat safe construction of the curves also for the intervals between the stations. It is very doubtful whether a similar construction would have been accepted when based upon the surface observations only. Now the consequence is that the section exhibits a deep and marked bulk of water with high temperatures and salinities, evidence that the Great Atlantic Current makes a curious serpentine bend in this region (it is not visible in the small-scale charts as for instance that on p. 96*). Such details may be of the greatest importance to our understanding of the physical and dynamical conditions in the ocean, but may easily escape observation through the generally much too open-meshed net of stations.

Large eddies and horizontal vortex movements are very conspicuous in the Norwegian Sea, and are probably quite common in many parts of the Ocean [Helland-Hansen and Nansen, 1909]. In August 1910 a number of stations were taken in the Faeroe-Shetland Channel from the "Michael Sars" and the Scottish exploration ship "Goldseeker". Leaving the discussion of the results to a subsequent chapter, I shall here only mention that the distribution of temperature, salinity and density was very complicated, great horizontal variations being observed within short distances. The observations may, however, be combined in such a way that a plausible series of vortices is indicated, which makes the intricate variations quite intelligible. Similar studies have not previously been made in the North Atlantic except in some small areas. When working up the results of the "Armauer Hansen" cruises, Professor Nansen and I [1926] have found great and numerous variations in those parts of the eastern North Atlantic where many stations have been taken in the course of time. The variations may to a great extent be accounted for in a reasonable way on the assumption of vertical oscillations, but it is most likely that eddies also enter as an ordinary part in the features of these regions.

Great and rather abrupt local variations due to currents and eddies make the utilization of serial observations from stations far apart very limited and many apparent results quite illusory. Even a short displacement may alter the results very appreciably. In those places where relatively many stations have been worked, an error in the determination of the ship's position may cause considerable error in the deduction of results. For furthering our knowledge of the physical and dynamical conditions in such oceans as the North Atlantic, observations scattered over the greater part of the ocean are now, upon the whole, of comparatively little value. What is needed is a detailed survey of the different regions. Even such

an important phenomenon as the Great Atlantic Current between America and Europe is probably very different from what is now generally believed, but the real conditions cannot be cleared up properly unless special investigations are made, with a very close net of stations. The "Michael Sars" observations from the North Atlantic are much too scattered to solve important problems, and the graphical representation of them in charts and sections, as well as the discussion, must for the greater part necessarily be rather schematic.

V. SHORT-PERIOD OSCILLATIONS.

21. Observations from the North Atlantic.

Earlier observations in the North Polar Basin and the Norwegian Sea had shown that even in the deep sea the repetition of a vertical series of observations sometimes gave results which differed from the first series with regard to the distribution of temperature, salinity and density [cf. HELLAND-HANSEN and NANSEN, 1909]. A certain temperature or salinity might be observed at a somewhat different level than found a relatively short while before. The phenomenon appears as a vertical displacement of the water-layers and may represent real vertical oscillations, caused by internal waves or other motions with a vertical component. In those places where the horizontal variations are great a purely horizontal displacement may, however, have the same effect upon the values observed. It may also be mentioned that it is not unlikely that the flowing water-masses occasionally are heterogeneous, showing variations in temperature and salinity with constant density. In such cases repeated observations at a fixed station may exhibit variations in the two first named elements without any dynamic significance.

In the "Michael Sars" Expedition observations at different depths were repeated at several stations, though not systematically except at Stat. 115 in the Faeroe-Shetland Channel. The observations are recorded in Table II. From the North Atlantic we have the following observations of this kind:

Stat. 10 in the Bay of Biscay, N. of Cape Finisterre. — At 193 metres practically no variations in 3 hours. — At 640 metres in 1·7 hours: no variation in salinity, which had the same value as at 457 metres. The last temperature observation was made by means of a Nansen-thermometer in an insulated Pettersson-Nansen water-bottle, showing an increase of temperature of 0·23° C and accordingly a decrease in σ_t of 0·04 units. The observations may indicate a considerable sinking of the water-layers (about 65 metres calculated from σ_t). — At 914 metres in 1·3 hours: decrease of salinity and density, corresponding to some 20 metres' sinking of the water-layers when calculated from the σ_t variations.

Stat. 25 B in the Cadiz Bay, S. of Cape St. Vincent. — At 366 metres in 3·2 hours: increase of temperature and salinity, σ_t practically constant. The vertical variations are rather small, especially in σ_t. The observations may indicate a sinking of the water-layers of some 15 metres at this depth.

Stat. 51, more than 500 naut. miles SW. of Fayal (the Azores). — At 400 metres in 0·8 hours: no variation in σ_t, but a small decrease of temperature and salinity (corresponding to a lifting of the water-layers of about 3 metres only).

Stat. 63, in the outskirts of the Sargasso Sea. — At 64 metres: at first, in 4·1 hours, an increase of temperature (0·28° C, corresponding to a sinking of the water-layers of about 6 metres), a decrease of salinity and density (doubtful), and then, in 1·8 hours, a decrease of temperature (0·13° C, corresponding to a lifting of about 3 metres). — At 457 metres: in the first 4·8 hours small variations in temperature and density, none in salinity. In the following 1·8 hours decrease of temperature and salinity, increase of density (about 13 metres' lifting of the water). — At 732 metres: no variations in the first 2·8 hours. In the following 1·8 hours increase of temperature and salinity, constant density.

Stat. 68, about 450 naut. miles SE. of Cape Race. — Several measurements were made at about 900 metres, but nothing definitely can be deduced from them. Due to strong wind and current the wire could not be brought in a vertical position; the depths recorded in Table II as 896, 901 and 905 metres are reduced from 914 metres on account of the inclination of the line. The 5 observations in question were made during 4·3 hours. Vertical oscillations of the water-layers have probably been quite insignificant if occurring at all.

Stat. 92, SW. of Ireland. — At 1006 metres in 2·9 hours: a small decrease of temperature and salinity indicates a lifting of the water-layers, while a simultaneous decrease of density indicates a sinking, so that nothing definite can be deduced from the observations.

The various data given above together with the approximate values of 10^8 E, are here brought together:

Stat.	Depth. Metres.	Time of Variation. Hours.	Variation in Depth. Metres.	Stability $10^8 E$
10	197	3	0	0
	640	1·7	65 down	40
	914	1·3	20 „	100
25 B	366	3·2	15 „	50
51	400	0·8	3 up	130
63	64	4·1	6 down	650
	„	1·8	3 up	„
	457	4·8	0	150
	„	1·8	13 up	„
	732	2·8	0	260
	„	1·8	0 ?	„
68	900	4·3	0 ?	200
93	1006	2·9	0 ?	80

The values found for the variation in depth are very uncertain. They may indicate that variations of this kind upon the whole are rather insignificant in the North Atlantic Ocean except in regions near the continental slope (Stats. 10 and 25 B).

The observations recorded above show no definite connection with the variations in stability. It is true that repeated observations have not been made within those water-layers where the stability has had a maximum and where boundary waves may be most likely to occur. At Stat. 63 near the outskirts of the Sargasso Sea the stability was very great in the upper water-layers, especially between 10 and 25 metres below the surface where we may speak of a "discontinuity-layer", and also at the depth of 64 metres the stability was very pronounced. The oscillations indicated at the latter depth may be real and suggest a more prominent primary wave at a higher level.

Our observations from the North Atlantic in 1910 offer only a meagre material for studying the problem of vertical oscillations or quasi-oscillations. Later on more observations have been obtained from the eastern North Atlantic, though not at all satisfactory for our purpose. After a thorough discussion of the various data available, Professor NANSEN and the present author [1926] have come to the conclusion that considerable vertical oscillations may occur in some regions especially near the continental shelf and banks, and that these oscillations are possibly, or even probably, connected with the tidal phenomenon, strong evidence being found for 12 hour (lunar) and 24 hour periods. The semi-diurnal period seems to dominate near the banks, at any rate in some water-layers, while the diurnal period is predominant farther out in the sea. The oscillations at some depths may be inverse to those at other depths (difference of phase 180°).

It is probable that some of the "Michael Sars" stations in the North Atlantic have been taken at places and times when vertical oscillations or quasi-oscillations have occurred, so that the serial observations do not represent the average conditions. For the greater number of the stations, however, this eventuality is not likely to be of any consequence.

22. Experiments in the Faeroe-Shetland Channel.

In the Faeroe-Shetland Channel special observations were made for a study of possible short-period variations in the vertical distribution of temperature, salinity and density. After a discussion of the results obtained from the Norwegian Sea, at a meeting in Copenhagen in August 1909 of the International Council for the Exploration of the Sea, it was agreed that investigations of submarine waves etc. should be performed if possible in the Faeroe-Shetland Channel, by means of the Danish, Scottish and Norwegian research ships. From the Danish side such investigations were made during 67 hours on May 23rd to 26th at 61° 27′ N. Lat. and 4° 33′ W. Long. where the depth to the bottom was 780 metres [M. KNUDSEN, 1911]. In August 1910 a collaboration was established between the Scottish explorations in the "Goldseeker" and the Norwegian in the "Michael Sars". Relatively many stations were worked by the two ships along four sectional lines between Shetland and the Faeroes (see the chart of stations, p. 95*). At two stations repeated observations were made during more than 24 hours on August 13th and 14th. The Scottish station (marked Sc. in the chart just mentioned) was situated at 61° 32′ N. Lat., 4° 19′ W. Long., bottom-depth 725 metres. The corresponding observations from the "Michael Sars" were made at Stat. 115, at 61° 0′ N. Lat., 2° 41′ W. Long., bottom-depth 580 metres. At all three stations in question the place was marked by means of an anchored buoy, the ship being kept close to the buoy when the observations were taken.

The observations at the "Michael Sars" station 115 are recorded in detail in Table II, and are represented in the upper figures on pp. 84* (temperature) and 85* (density). In some cases determinations of salinity and consequently also of density are missing, while the temperature observations are so numerous that the curves for every hundred metres from the surface to 500 metres (incl.) may be drawn fairly safely. The vertical variations of salinity are frequently so slight that small errors in the determinations may have an appreciable effect upon the apparent results with regard to the oscillations. We shall, therefore, in the following especially pay attention to the temperature variations.

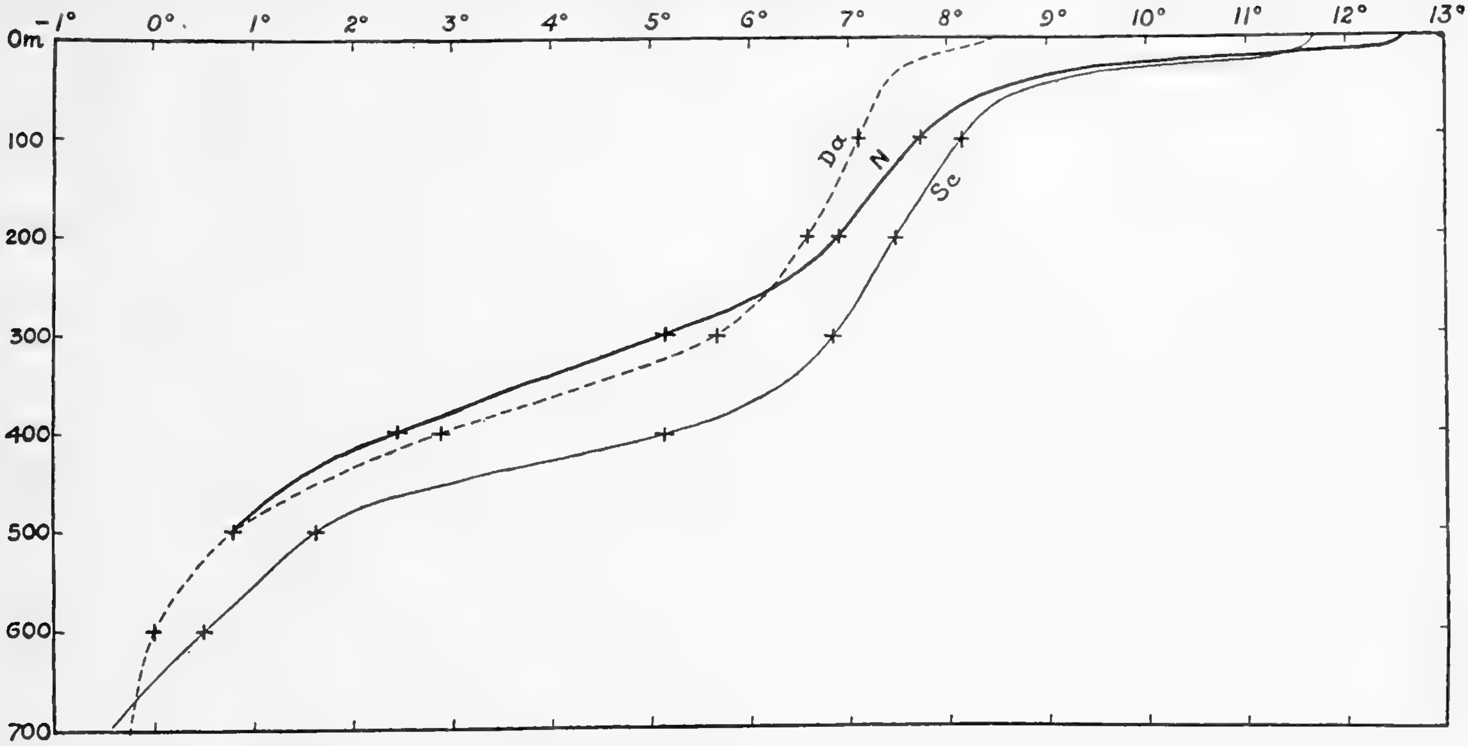


Fig. 1. The vertical distribution of temperature at the Danish station (*Da*, May 23.—26.), the "Michael Sars" station 115 (*N*, August 13.—14.) and the Scottish station (*Sc*, August 13.—14.) in the Faeroe-Shetland Channel.

Fig. 1 illustrates the vertical distribution of temperature at our Stat. 115 (the curve marked N) and the Scottish station (Sc.) in August, and at the Danish station (Da.) in May. The average temperatures found by harmonic analysis (τ_m in the table, section 23) have been used for the construction of the curves.

The temperature at intermediate depths is much higher at the Scottish station than at Stat. 115, so that for instance the temperature found at the latter station at 200 metres is found at about 300 metres at the former, and 300 metres at Stat. 115 corresponds to 400 at the other with regard to temperature. Similar conditions are displayed by the salinities. The direct observations of salinity give the following mean values:

	Stat. 115	Stat. Sc.
Surface	35·190	35·234
100 metres	·195	·226
200 „	·144	·201
300 „	·053	·151
400 „	34·877	·064
500 „	·872	34·892
600 „	—	·891

In the same way we find the following average values of σ_t:

	Stat. 115	Stat. Sc.
Surface	26·635	26·835
100 metres	27·484	27·452
200 „	·565	·538
300 „	·710	·588
400 „	·859	·725
500 „	·973	·940
600 „	—	28 ·016

The difference in depth of the intermediate water-layers at the two stations is not found to be exactly the same when estimated from salinity or density as when estimated from temperature. The discrepancy is but very small, however, and we have evidently to deal with parts of the same water-layers even if the salinity anomaly is a little different, be it due to errors of observation or to different mixing processes. We may at any rate conclude that the same intermediate water-layers are situated about 100 metres deeper at the Scottish station than at Stat. 115.

The increase of surface temperature from May to August is conspicuous (see Fig. 1), but even in May the heating at the surface is so advanced that a considerable temperature-gradient is found in the uppermost water-strata, between the surface and 25 metres. This quasi discontinuity is much more marked in August when the temperature at the stations in question decreases very rapidly

downwards, from 10 to 50 metres say. From about 50 metres to 200 or 300 metres below the surface the temperature decreases at a slower rate, but further downwards to some 500 metres the temperature gradient is again very great. We have here two such "steps" as were mentioned above (section 20).

The temporal variations of τ, S or σ_t now dealt with, whether periodic or not, may *a priori* be expected to be greatest at those depths where the vertical gradients of these elements are greatest. The differance $\tau_{max} - \tau_{min}$ between the highest and the lowest temperatures observed is given in column 7 of the table on p. 27. We find upon the whole that this difference is greater with a great vertical temperature-gradient than with a small, but no direct proportionality exists. We have, for instance, much the same vertical temperature-gradient at 300 metres as at 400 metres at Stat. 115, but the values of $\tau_{max} - \tau_{min}$ are very different.

23 Harmonic Analysis. Tidal Variations.

The oscillations found by earlier investigations seemed to be connected partly with the tidal phenomena, and later observations have given further support to this conclusion, as mentioned above. The temporal variations observed at our Stat. 115 seem also at first sight, at any rate at some levels, to exhibit a periodicity in accordance with the tidal periods. As the influence of the moon generally is predominant in the tides it is reasonable to use lunar hours as the unit of time (1·035 solar hours, reckoned from the upper passage of the moon).

Values have been interpolated for every lunar hour, Greenwich time. We have selected this division of the time also for the analysis of the Scottish observations, so that we get the interpolated records of temperature for both stations referred to the same moments of time.

The upper passage of the moon occurred at Greenwich on August 12th at $17^h\ 31^m$ G. M. T. and on August 13th at $18^h\ 15^m$ (civil time, the day reckoned from midnight to midnight). At Stat. 115 the observations commenced early in the morning on August 13th, so that data may be obtained for 24 lunar hours beginning with the 12th lunar hour. At the Scottish station the observations commenced about 5 hours later.

The temperature-values interpolated for every lunar hour have been subjected to harmonic analysis. Calculations have been made according to the formula

$$\tau = \tau_m + \frac{A}{2} \cos 15^\circ (t - k_1) + \frac{B}{2} \cos 30^\circ (t - k_2)$$

where τ is the temperature at the lunar hour t, τ_m the mean temperature, A the total variation (the double amplitude) due to a diurnal, B to a semi-diurnal harmonic oscillation, k_1 the time (expressed in lunar hours) when the maximum occurs at the diurnal, k_2 at the semi-diurnal variations.

The first cosine-term in the formula above corresponds to the small elliptic moon-tide, M_1, which is generally of but quite secondary importance. It has a period of 24·84 (ordinary) hours = 24 lunar hours. A much greater weight is in most cases ascribed to the partial tides O with a period of 25·82 hours and K_1 with a period of 23·93 hours. As our observations embrace 24 lunar hours only, it is impossible to separate the different partial tides of the diurnal type, and it is much the same which of the periods is selected for the analysis. As M_1 has a period just between O and K_1, and it is most convenient to use the horary angle of 15° (referred to lunar hours) for the calculations, the harmonic constants have been computed for M_1 as representing the total diurnal variation. The result gives at any rate a rough approximation only and is very uncertain on account of the shortness of the series of observations.

The second cosine-term in the formula above corresponds to the chief moon-tide M_2, which in our case can not be kept distinct from the semi-diurnal solar tide S_2. From the Danish observations which extended over as much as 67 hours, KNUDSEN [1911] has made an attempt to separate the two periods with regard to the temperatures at 400 metres. His computations indicate an unexpectedly great amplitude due to the solar period. The short series of observations at our Stat. 115 and the Scottish station do not permit an attempt to separate the M_2 and S_2 periods. Both of them will be included in our computations.

The harmonic analysis has been carried through with regard to the temperatures observed at the surface and at every hundred metres of depth below the surface at Stat. 115 and the Scottish station.[1]) The results are combined in the following table, where also are included the data published by KNUDSEN for the Danish station in May.

The amplitudes found by the harmonic analysis are upon the whole comparatively great, indicating that the temperature variations have been to a considerable extent diurnal and semi-diurnal. For the sake of brevity we shall in the following name these partial variations the *tidal* variations. The term is not exhaustive and may be misleading, because some of the tidal periods possible are

[1]) The Scottish observations are published in Bulletin Hydrographique pour l'Année Juillet 1910 — Juin 1911 [Copenhagen 1912]. The present author is indebted to Dr. A. BOWMAN, Superintendent of the Fishery Board for Scotland, for detailed records of the exact time when the observations were taken.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	t_m	k_1	k_2	A	B	C	$t_{max.} - t_{min.}$	$\frac{B}{t_{max.} - t_{min.}}$	$\frac{\Sigma\|R\|}{\Sigma\|\Delta t\|}$	$\frac{A}{B}$	$10^{-2} \frac{dz}{dt}$	$A \frac{dz}{dt}$	$B \frac{dz}{dt}$	$C \frac{dz}{dt}$
Surface:														
Stat. 115	12·60	19·6	6·9	0·10	0·11	0·17	0·30	0·4	0·76	0·9	—	—	—	—
„ Sc.	11·69	15·5	6·6	·30	·32	·55	·66	·5	·52	·9	—	—	—	—
„ Da.	8·50	—	4·2	—	·02	—	·80	·0	—	—	—	—	—	—
100 m.:														
Stat. 115	7·74	17·0	6·3	0·19	0·17	0·30	0·29	0·6	0·23	1·2	0·9	18	15	28
„ Sc.	8·16	12·3	0·7	·35	·37	·60	·72	·5	·51	0·9	1·1	39	42	67
„ Da.	7·10	—	8·0	—	·04	—	·50	·1	—	—	2·0	—	8	—
200 m.:														
Stat. 115	6·90	15·9	8·4	0·15	0·11	0·22	0·38	0·3	0·83	1·3	1·1	16	12	24
„ Sc.	7·47	14·2	11·2	·06	·32	·36	·61	·5	·64	0·2	1·9	11	58	66
„ Da.	6·58	—	8·0	—	·06	—	·70	·1	—	—	1·7	—	10	—
300 m.:														
Stat. 115	5·15	17·7	9·3	0·22	0·60	0·77	0·86	0·7	0·54	0·4	0·4	9	24	31
„ Sc.	6·83	17·7	11·6	·07	·18	·22	·76	·2	·99	·4	1·2	8	22	26
„ Da.	5·66	—	7·9	—	·21	—	1·00	·2	—	—	0·6	—	12	—
400 m.:														
Stat. 115	2·43	9·0	9·5	0·25	0·18	0·34	0·32	0·6	0·26	1·4	0·4	10	7	14
„ Sc.	5·18	4·4	9·2	·32	·39	·60	1·10	·4	·57	0·8	·3	9	11	17
„ Da.	2·90	—	8·7	—	·85	—	2·70	·3	—	—	·4	—	31	—
500 m.:														
Stat. 115	0·80	11·3	6·6	0·05	0·03	0·07	0·20	0·2	0·87	1·5	1·0	5	3	7
„ Sc.	1·64	5·2	11·1	·09	·36	·40	·48	·7	·47	0·3	0·7	6	24	27
„ Da......	0·83	—	10·0	—	·34	—	1·00	·3	—	—	·7	—	24	—
600 m.:														
Stat. 115	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ Sc.	0·50	1·2	7·3	0·28	0·26	0·42	0·51	0·5	0·41	1·1	0·9	25	24	38
„ Da.	0·01	—	0·0	—	·04	—	·40	·1	—	—	2·0	—	8	—

not included, while on the other hand daily or casual variations may be included which have nothing to do with the tidal phenomena. It must also be emphasized that *the results are very doubtful on account of the shortness of our series*, as mentioned above. *The discussion of the observations may, however, serve to form a working hypothesis for further investigations, for which reason we shall go into details in spite of the fact that the observations are very incomplete.*

The maximum variations seemingly caused by diurnal and semi-diurnal oscillations separately, appear in columns 4 and 5 in the table above. Upon adding together for each lunar hour the two values of the temperature deviations ascribed to these oscillations, we obtain a new series of figures. In column 6 of the table the maximum difference between the latter figures is entered *(C)*. It is in many cases comparatively very great, at some depths even as great as the difference between the maximum and minimum temperatures observed.

KNUDSEN has tabulated the values of $\frac{B}{t_{max} - t_{min}}$ for the Danish station and found a maximum value of this quantity amounting to 0·3 at 400 and 500 metres where the temperature changed most quickly with the depth. In column 8 of our table above the corresponding values are recorded for Stats. 115 and Sc., together with the values given by KNUDSEN. At the Norwegian and Scottish stations these values are in nearly all cases larger than at the Danish station, which may be due to the shortness of our series of observations at the two former stations compared with that at the latter. The maximum values (0·6 — 0·7) are found at 100, 300 and 400 metres at Stat. 115,

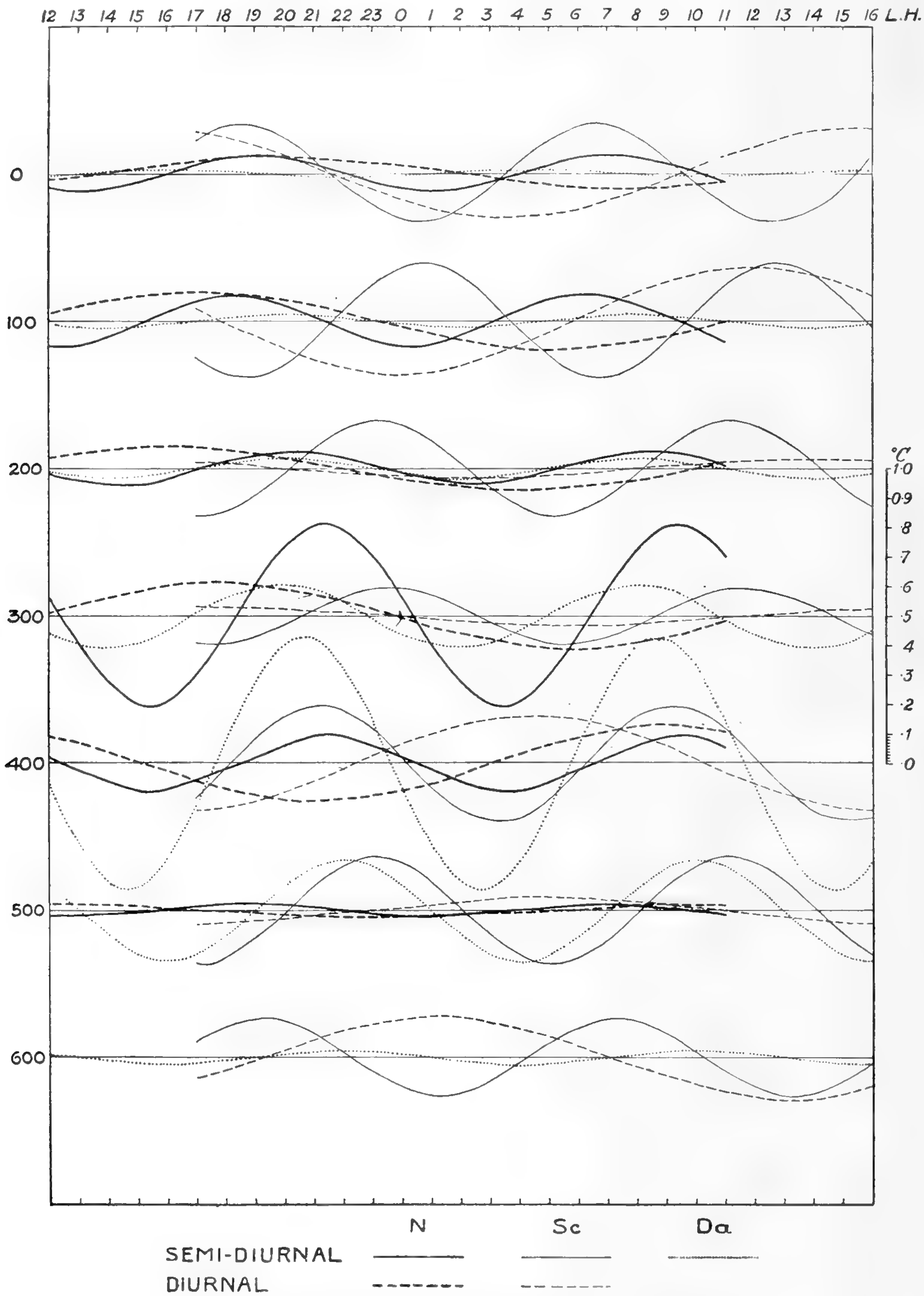


Fig. 2. Semi-diurnal and diurnal temperature-variations separately.

and at 500 metres at the Scottish station, without any very definite accordance with the vertical temperature-gradient. The quantity $\frac{C}{\tau_{max} - \tau_{min}}$ gives, of course, higher values still.

We may in different ways find an expression of the part played by the tidal variations in the total variations. If for each lunar hour we subtract the deviation of temperature due to the calculated tidal effects from the deviation ($\triangle\tau$) of the observed (or interpolated) temperature from the average temperature we obtain a remainder, R. The sum for the whole series of 24 lunar hours of the numerical values of $\triangle\tau$ and the corresponding sum of R have been found, and the ratio $\frac{\Sigma\,|\,R\,|}{\Sigma\,|\,\triangle\tau\,|}$ calculated. The results are recorded in column 9 of the table above. The figures show that in most cases the residual variations are on an average considerably smaller than the total variations. Especially at 100 and 400 metres at Stat. 115 the total variations are nearly covered by the tidal variations. At the Scottish station the closest coincidence between the total and the tidal variations is found in the deep water-stratum at 600 metres, but it is also fairly good at the other depths except at 300 metres. The course of the vertical variations in the value of $\frac{\Sigma\,|\,R\,|}{\Sigma\,|\,\triangle\tau\,|}$ between 100 and 400 metres at Stat. 115 corresponds to that between 200 and 500 metres at the Scottish station, in accordance with the above mentioned difference of temperature between the two stations.

The partial temperature-"tides" are illustrated in Fig. 2, where the time (in lunar hours, L. H.) is plotted along the abscissa at the top of the figure, and the deviations from the average temperature for each single depth along the ordinate (scale to the right in the figure). Most of the tidal variations are very marked, especially at 300 and 400 metres below the surface, where the vertical temperature-gradient is great.

The amplitude of the temperature variations must not, of course, be confounded with the amplitude of the underlying motions of the water-layers. In a "discontinuity-layer" even a fairly large temperature-variation may correspond to a small displacement only. When we assume that the variations in temperature are chiefly caused by vertical or horizontal movements it is important for a study of the kinematical conditions to have the temperature observations converted into values of height or length. A vertical displacement of the water-layers will generally be connected with a horizontal one, and we should not one-sidedly ascribe the variations either to purely vertical or to purely horizontal movements. We may, however, in any case estimate the variations in depth of the isothermal surfaces of τ_m along the station-vertical. From curves representing the mean vertical distribution of temperature (cf. Fig. 1) we may find approximately the vertical distance corresponding to a variation of 0·01° C., or $10^{-2}\frac{dz}{d\tau}$ metres (the reciprocal value of the vertical temperature-gradient). A valuation of this kind has been made for the stations in question and the results are recorded in column 11 of the table on p. 27. By means of the numbers recorded in columns 4—6 of the table we may then find approximately the assumed diurnal and semi-diurnal, as well as the combined, variations in depth of the isothermal surfaces in question. The results are recorded in columns 12—14.

The lower figures on pp. 84* and 85* illustrate the total variations in height — "tidal" and otherwise — at Stat. 115, calculated in the manner just mentioned.[1])

24. Diurnal Variations.

The daily variations in surface temperature are quite considerable at Stats. 115 and Sc. A daily variation may be expected on account of the heating by day and cooling by night. The harmonic analysis gives at Stat. 115 a maximum temperature in the daily variation at $k_1 = 19{\cdot}6$ lunar hours, *i. e.* August 13th, 13^h 43^m local mean time. The total amplitude in the daily variation is 0·11° C. It is probably due to the heating during the day and cooling during the night. At the Scottish station the corresponding maximum in the daily variation occurs early in the forenoon, at about 10 o'clock, the total amplitude being 0·30° C. It may be due to a combination of the daily variations just mentioned and real tidal variations. But beside these daily variations we find half-daily variations with nearly the same amplitudes (0·11 and 0·32° C.). k_2 has practically the same value at both stations, corresponding to temperature maxima shortly after noon and after midnight on August 13th — 14th. A closer examination of the observations of temperature and salinity shows that the surface currents have evidently oscillated in a horizontal direction, which was also to be expected, rotary tidal currents being distinctly discernible in the Faeroe-Shetland Channel after elimination of the rest current. The greater amplitude of the semi-diurnal temperature variation at Stat. Sc. compared with Stat. 115 is probably explained by greater horizontal variations in temperature at the former station than at the latter. If a semi-diurnal oscillation occurs at the

[1])The scales of lunar hours at the bottom of the figures are unfortunately incorrect because of a misinterpretation of some nautical tables casually used.

surface, a diurnal oscillation of tidal character may just as well occur.

The diurnal variations at 100 metres and deeper cannot be accounted for by variations in direct heating and cooling. At 300 metres the phase of oscillation (k_1) is exactly the same at Stat. 115 as at the Scottish station, but at all other depths there is a marked difference, the maximum in the diurnal variation occurring earlier at Stat. Sc. than at Stat. 115. The difference is between 4 and 5 hours at 0, 100 and 400 metres where the amplitudes are quite appreciable at both stations. At 500 metres where the amplitudes are small the phase difference is found to be 6 hours. The vertical variations in k_1 at the two stations are seen from the table p. 27, and are also demonstrated by the curves in Fig. 2. It may especially be noticed that the values of k_1 are comparatively high in the upper 300 metres and low from 400 metres downwards. The difference in k_1 between 300 metres and 400—500 metres at Stat. Sc. is 12—13 lunar hours, or a difference of phase of approximately 180°. The difference is smaller at Stat. 115. It must be kept in mind, however, that the values of k_1 found refer to the dates of observation only, and cannot claim any general validity, because the analysis includes several diurnal periods of different length and with unknown amplitudes. They may chiefly serve to demonstrate that *the phase of the total diurnal variation seems to vary not only from station to station but in vertical direction too.*

The numbers in column 12 of the table p. 27 do not exhibit the same variations vertically as the temperature records in column 4. The former figures show an absolute maximum of diurnal oscillation at 100 metres below the surface at both of the stations 115 and Sc. The amplitude is especially great at Stat. Sc., more than twice the amplitude at Stat. 115. At Stat. 115 the amplitude is a little lower at 200 metres than at 100, while at Stat. Sc. it is very much lower at 200 metres than at 100, and less than at 200 metres at the other station. At 300 and 400 metres the oscillations have been still more reduced, having practically the same amplitude at both depths and both stations. At 500 metres we find absolute minima. At 600 metres the amplitude at the Scottish station is again comparatively great.

This seems to indicate that the diurnal variation in the depth of the isothermal surfaces has been most marked at about 100 metres below the surface. It might be suposed to be the effect of a boundary wave along the upper "discontinuity-layer".

A great many observations were made at the Scottish station at 10, 20, 30 and 50 metres, but they show so many sudden variations in temperature and are taken at such irregular intervals of time that it is impossible to perform the interpolations necessary for a harmonic analysis, except in the case of 50 metres. The analysis gives the following equation for this depth:

$$\tau_{50} = 8{\cdot}72 + 0{\cdot}14 \cos 15^\circ (t - 20{\cdot}7) + 0{\cdot}34 \cos 30^\circ (t - 0{\cdot}9)$$

It follows that the phase of the diurnal variation is not very different from that at the surface, but the maximum at 50 metres occurs nearly 4 hours later than at 100 metres. The amplitude is 0·14, so that A = 0·28, which is a smaller temperature variation than was found at the surface and 100 metres. It is, unfortunately, impossible to determine $\frac{dz}{d\tau}$ for 50 metres in a satisfactory manner, but there are strong reasons to believe that it has a lower value than at 100 metres, which leads to the conclusion that a possible vertical motion has possessed a smaller amplitude at 50 metres than at 100. *The diurnal wave should, therefore, have had its maximum development at about 100 metres at the Scottish station and not in the upper "discontinuity-layer".* The vertical temperature-gradient is not particularly great at 100 metres. It is much greater at 400 metres where, however, the vertical displacements are small.

The great amplitude at 600 metres at the Scottish station is remarkable. The amplitude is quite insignificant at 500 metres, as also at the deepest observations at Stat. 115 (500 metres, with an average temperature which is only 0·30° C. higher than at Stat. Sc., 600 metres). k_1 has also a value at Stat. Sc. 600 metres which differs appreciably from that at higher levels. It may suggest the possibility of a particular oscillation in the deep-water (the "bottom-water") of the Norwegian Sea, if it is not altogether casual.

25. Semi-Diurnal Variations.

The semi-diurnal variations at Stat. 115 are different from those at the Scottish station with regard to both amplitude and phase (see Fig. 2 and the table p. 27).

We have already discussed the variations at the surface. At 100 metres at Stat. 115 the amplitude of temperature is but slightly higher than at the surface, and the phase is very nearly the same. At the Scottish station the temperature variation is also somewhat greater, but the phase difference is 6 hours (180°). The harmonic constants for 50 metres (the equation section 24) shows the same phase as at 100 metres, but a much greater temperature-amplitude, B being 0·68 against 0·37° C. The conditions may suggest a boundary wave in the upper "discontinuity-layer" at this station as far as the semi-diurnal variations are concerned.

At Stat. 115 k_2 increases all the way from 100 to 400 metres, at first rapidly, then more and more slowly, the

difference between 100 and 400 metres being 3 hours. The amplitude displays at first a decrease, and then an increase to a very considerable maximum in the "discontinuity-layer" at 300 metres. Thence the amplitude decreases rapidly to almost nought ($B = 0{\cdot}03°$ C. only) at 500 metres, where k_2 has nearly the same value as at the surface or at 100 metres. At the Scottish station the conditions are different: k_2 shows irregular variations, and B has its maximum at 400 metres with but a slow decrease towards the bottom-layers. As to the semi-diurnal variations we have data for comparison from the Danish station worked 3 months earlier (table p. 27). At this station the amplitudes were much smaller in the upper 200 metres than at either of the other stations. A large maximum is found at 400 metres, and a considerable amplitude at 500 metres, while at 600 metres the semi-diurnal temperature variation is but small and much less than at the Scottish station from the same region in August. At most levels the values of k_2 at Stat. Da. do not differ much from those found at Stat. 115, but more from those at Stat. Sc., in spite of the short distance to the latter station.

When converting the temperature-variations into vertical displacements we find *at all levels except 300 metres greater semi-diurnal oscillations at the Scottish station in the central part of the Faeroe-Shetland Channel than at Stat. 115.* At Stat. Sc. an absolute maximum of no less than 58 metres' total amplitude is calculated for the variations in depth of the isothermal surfaces at about 200 metres. It seems very likely that comparatively large vertical displacements have really occurred at this station at 200 metres, and at 100 metres too. A minimum is found at 400 metres, while in the deeper layers the amplitude is fairly great again. At Stat. 115 a maximum oscillation (24 metres) is found at 300 metres, with a rapid decrease downwards to some 3 metres only at 500 metres' depth below the surface. At the Danish station the corresponding variations increase slowly from 8 metres at 100 metres' depth to 12 at 300 metres, and then quickly to a maximum (31 metres) at 400. At 500 metres the oscillation is found to be of the same magnitude as at the Scottish station (24 metres), while at 600 metres it is much less again.

We thus find *a great variability in the appearance of the semi-diurnal temperature-oscillations, which seem to be different not only in amplitude but also in phase in vertical direction, to change from one station to another within the same area, and also to be subject to variations with time as regards the harmonic constants.*

26. The Ratio between the Diurnal and Semi-Diurnal Variations. The Combined Variations.

In column 10 of the table on p. 27 the ratio between the amplitude of the diurnal variation (A) and that of the semi-diurnal (B) is recorded. In the rise and fall of the sea surface with the tides the diurnal variations are generally of but secondary importance compared with the semi-diurnal. The ratio between the amplitudes expressed by $\frac{K_1 + O}{M_2 + S_2}$ should, according to the equilibrium theory of the tides, be equal to 0·68, but is in the great majority of cases much smaller [KRÜMMEL, 1911]. In the Atlantic area it is mostly 0·1—0·3 only. In some regions, especially in low latitudes, the ratio may attain comparatively large values, as is also the case in the Baltic. At Thorshavn it has the relatively high value of 0·73, while along the west coast of Norway it is only about 0·1.

The corresponding ratio $\frac{A}{B}$ found for the temperature variations here dealt with has remarkably high values. At Stat. 115 it is between 0·9 and 1·5 at all depths except at 300 metres where it amounts to 0·4 only. At this station the diurnal temperature-variations seem to be dominant in most water-layers. At Stat. Sc. the value of $\frac{A}{B}$ is smaller than at Stat. 115 at all depths from 100 to 500 metres. At the Scottish station the semi-diurnal variations are especially predominating at 200, 300 and 500 metres. In the deep water at 600 metres the ratio is above 1 at this station too, and at 100 and 400 metres the diurnal variation is nearly as great as the semi-diurnal. KNUDSEN has computed the constants of the O-period in temperature at 400 metres at the Danish station. The (double) amplitude was found to be 0·48, so that the ratio between the amplitudes of O and M is 0·6, which agrees fairly well with the number 0·8 found for the same depth at the Scottish station not far away.

The ratio between the diurnal and semi-diurnal temperature-oscillations thus seems to vary both in vertical and horizontal direction in the Faeroe-Shetland Channel. At some depths and in some regions the semi-diurnal variations in temperature seem to predominate in much the same way as is usual in the tides, while elsewhere the diurnal periods appear to have more bearing on the variations within the sea than on the tidal movements observed at the coasts.

By a summation of the departures due to the diurnal and semi-diurnal variations we obtain the variations illustrated by the curves in Fig. 3. The differences between

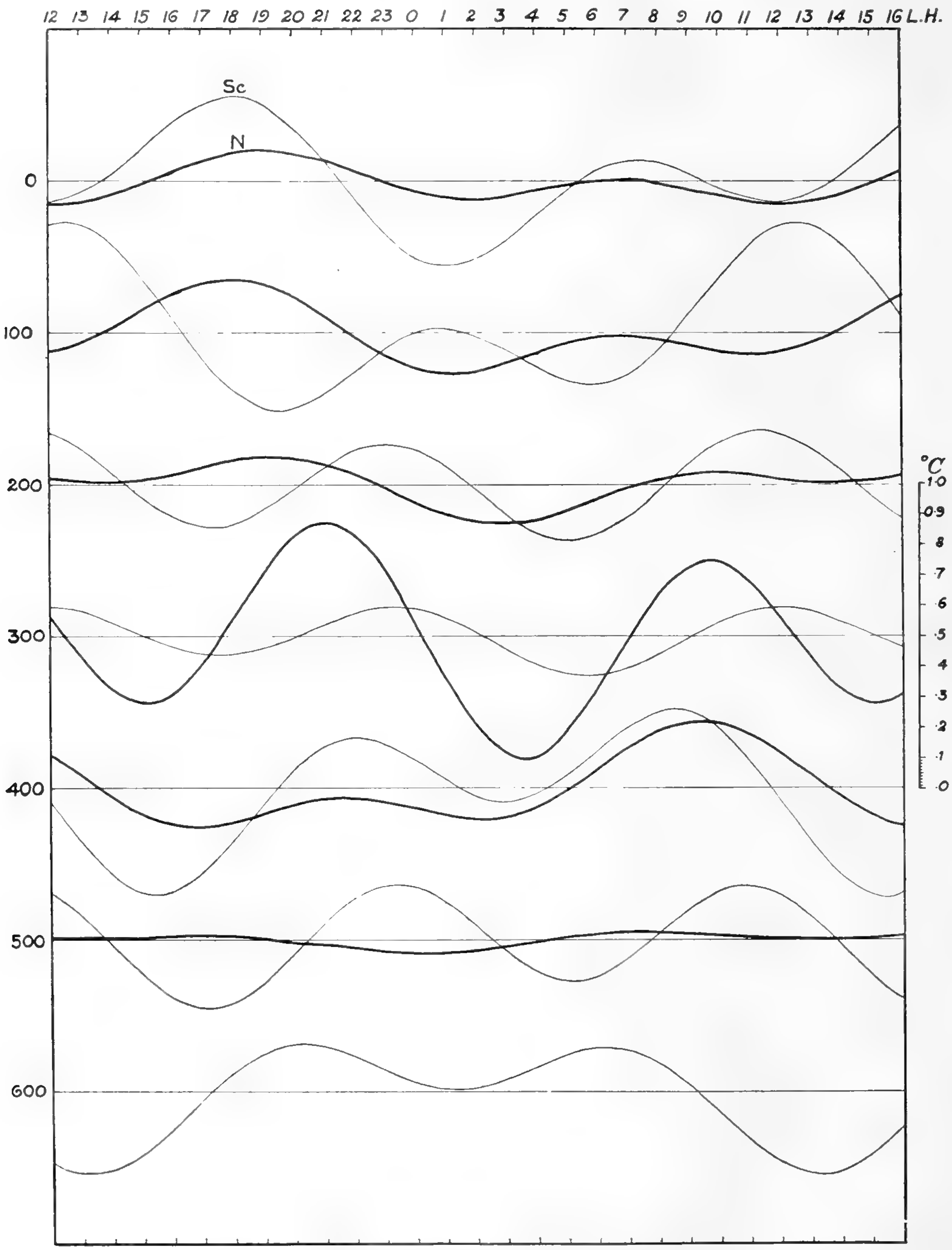


Fig. 3. Combined diurnal and semi-diurnal temperature variations at Stat. 115 *(N)* and the Scottish station *(Sc)*.

the highest and lowest temperature found in this way are recorded in column 6 *(C)* of the table p. 27. As a result of the relatively great influence of the diurnal variations, the daily disparity seems to be very great at some depths. If further the difference between k_1 and k_2 varies, the interval between two successive maxima or minima may be subject to comparatively great changes. In the following table records are given of the interval in lunar hours between the extremes, together with the variation in temperature due to the combined effect of the diurnal and semi-diurnal variations. The first minimum after the upper passage of the moon is numbered I, and the records start from this minimum. It corresponds to the first "upheaval" of the water-layer in question after the moon's passage. Δt means the time interval between the extremes, and $10^2 \Delta r$ the temperature variation in $^1/_{100}$° C.

	Min. I to Max		Max. to Min. II		Min. II to Max.		Max. to Min. I	
	Δt	$10^2 \Delta r$	Δt	$10^2 \Delta r$	Δt	$10^2 \Delta r$	Δt	$10^2 \Delta r$
0 m: 115	5·0	6	5·4	− 7	6·9	17	6·7	−16
Sc.	6·3	35	4·4	−14	6·3	34	7·0	−55
100 m: 115	5·4	12	4·4	− 6	6·9	24	7·3	−30
Sc.	6·9	52	6·8	−60	5·6	27	4·7	−19
200 m: 115	6·9	16	3·8	− 3	5·7	9	7·6	−22
Sc.	6·3	36	5·9	−31	5·8	27	6·0	−32
300 m: 115	6·0	63	5·5	−46	6·0	60	6·5	−77
Sc.	6·4	22	5·6	− 16	5·7	15	6·3	−21
400 m: 115	7·3	31	7·5	−34	4·8	9	4·4	− 6
Sc.	5·8	30	6·8	− 60	6·8	51	4·6	−21
500 m: 115	7·2	7	5·5	− 2	3·7	1	7·6	− 5
Sc.	5·6	31	6·4	−40	6·2	40	5·8	−31
600 m: Sc.	5·0	14	7·1	−42	7·0	42	4·9	−14

On the assumption that $\frac{A}{B}$ and $k_1 - k_2$ may actually vary as much as our computations seem to show, the above table gives an illustrating example of the disparity in temperature variations which may be encountered in the sea as an effect of diurnal and semi-diurnal oscillations only. We find for instance at Stat. 115 that at 400 metres the interval of time from the first minimum to the second was as much as nearly 15 lunar hours, but the next interval to a minimum was only a little more than 9 lunar hours, while the corresponding intervals at 300 metres were 11.5 and 12.5 lunar hours. The disparity which may exist with regard to the amplitude of temperature is also demonstrated in the table above.

When examining variations of temperature in relation to the tides we are apt to look for periods of 12 and 24 lunar hours. The results now arrived at indicate, however, that in many cases the 12 hour period may be quite distorted and unrecognizable unless the observations are subjected to harmonic analysis. In such cases the observations must embrace 24 hours at least.

If we have to deal with 12 and 24 hour periods only, the variations will repeat themselves after 24 hours, regardless of the ratio between A and B and the phase difference $k_1 - k_2$. But it is possible, or even probable, that at least 4 different tidal periods have to be considered: M_2, S_2, O and K_1. In that case the final result will depend upon the difference of amplitude and phase between these "waves" mutually, and we may expect a still greater variability which, to begin with, may in many cases look very irregular and seemingly without any connection with the tides.

The combined effect of the diurnal and semi-diurnal variations when converted into vertical oscillations is illustrated in Fig. 4 (the scale of the oscillations, in metres, to the right in the figure).

In agreement with what has been said above we find at *Stat. 115* comparatively great oscillations in the upper 300 metres, $C \frac{dz}{dr}$ being between 24 and 31 metres (cf. table p. 27), and a decrease deeper down to 7 metres only, at about 500 metres' depth.

At *Stat. Sc.* the corresponding oscillations were very great at about 100 and 200 metres. The isothermal surface of 8·16° C was on an average found at 100 metres below the surface of the sea at the Scottish station, but owing to diurnal and semi-diurnal variations (other variations disregarded) it was apparently lifted nearly to the level of 70 metres on August 13th between 13 h and 14 h G.M.T. (19—20 L. H.), and pressed as far down as about 140 metres below the sea surface on August 14th between 7 h and 8 h G.M.T. (about 13 L. H.), the calculated difference of depth being 67 metres. Tidal variations of the same amplitude were found at about 200 metres. The total amplitude was much smaller further down, with a minimum of $C \frac{dz}{dr} = 17$ metres at about 400 metres, from where it increased to 38 metres at about 600 metres below the surface. The apparent vertical oscillations of the isothermal surface caused by tidal variations were much greater at this Scottish station than at Stat. 115 except at 300 metres, where the ratio was inversed, and at 400 metres, where the difference was but small.

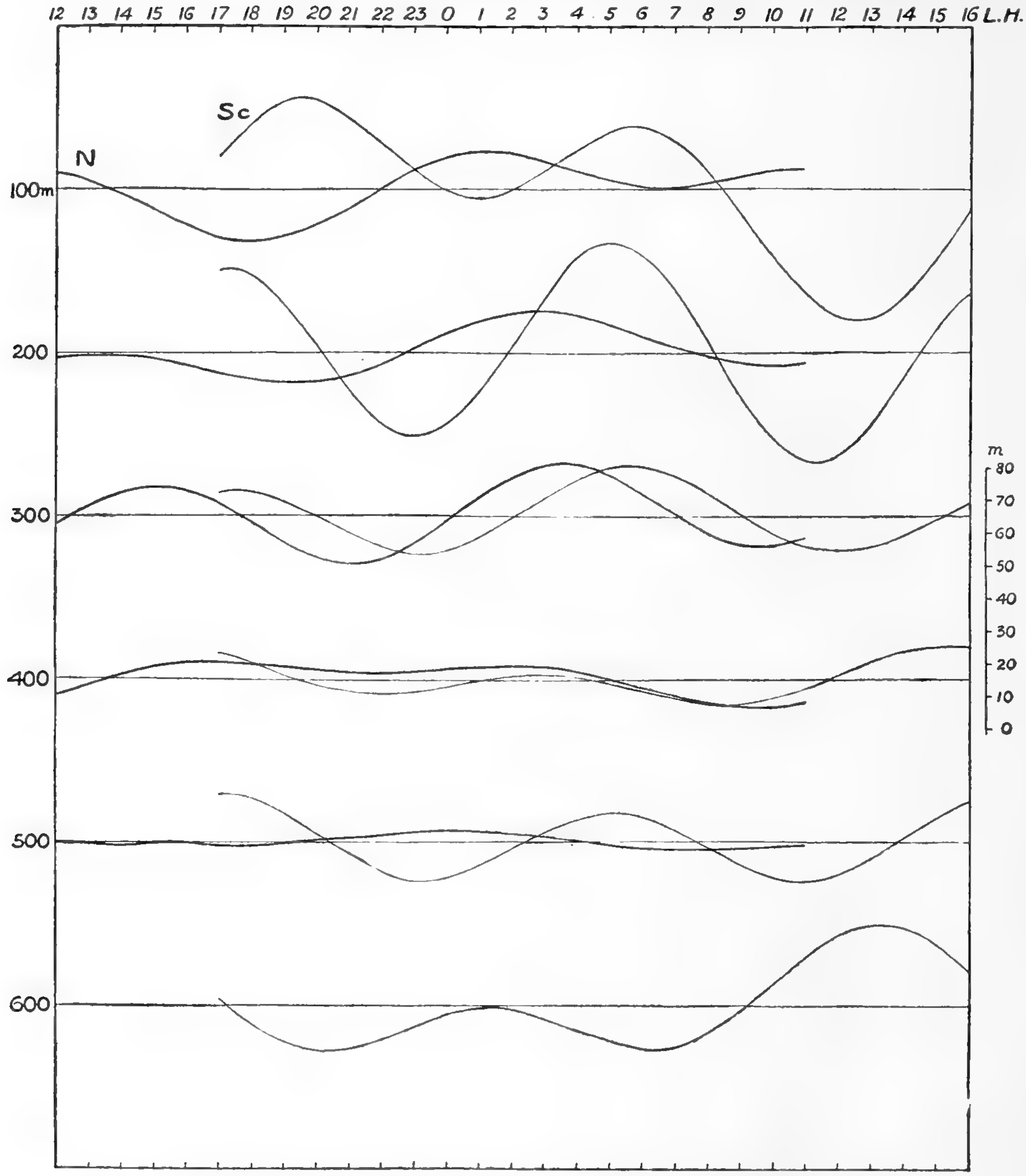


Fig. 4. Combined diurnal and semi-diurnal variations of temperature, converted into vertical oscillations in metres.

27. The Residual Variations.

It was mentioned above (section 23) that the greater part of the variations in temperature at Stats. 115 and Sc., were covered by the diurnal and semi-diurnal variations hitherto discussed. The curves in Fig. 5 illustrate the variations remaining after elimination of the 12 and 24 lunar hours' variations, with the apparent vertical displacement as argument along the ordinate. This figure may be compared with Fig. 4, both figures having the same scale for vertical distance.

The residual variations are rather irregular. In some cases they seem to be simultaneous and fairly uniform through different depths, as for instance during many hours at Stat. 115 at 200 and 300 metres, or between 1 and 6 L. H. at the Scottish Station through all depths from 100 to 400 metres. There is evidently no definite connection between the appearance of these oscillations

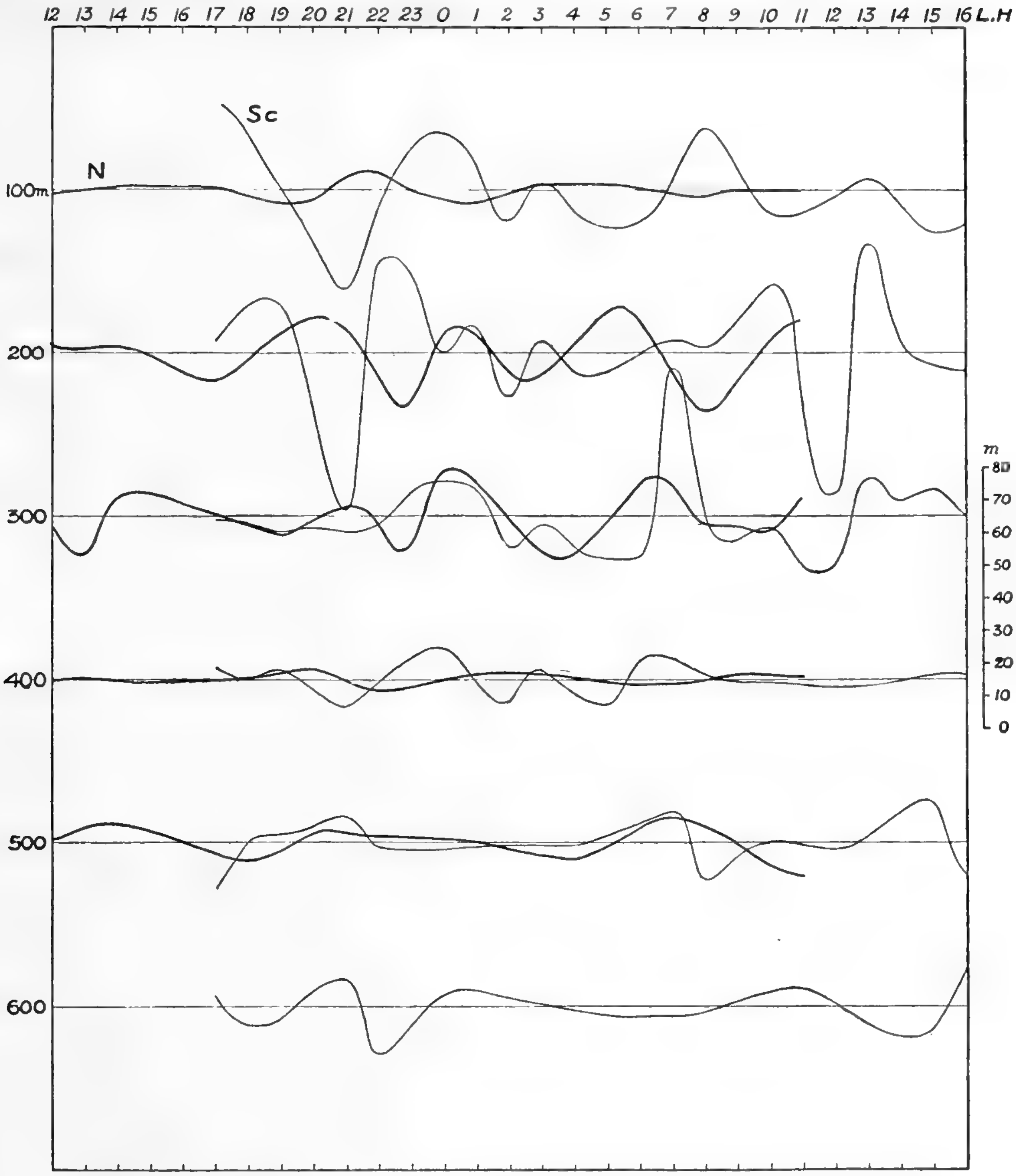


Fig. 5. Residual variations, in metres, after elimination of the diurnal and semi-diurnal variations.

and the vertical gradient of temperature. Comparatively great oscillations may seemingly appear at various depths, independently of the conditions at other levels above or below.

At Stat. 115 these variations are practically insignificant at 100 and 400 metres, where they are quite subordinate in proportion to the diurnal and semi-diurnal variations. They are most marked at 200 and 300 metres. The amplitudes do not differ so very much within each layer, but nothing can be made out with regard to definite periods.

At Stat. Sc. some few of the variations at 100, 200 and 300 metres are very great in comparison with the others. The curves from these depths remind one of curves for damped oscillations. Our curves represent the variations at a fixed station, with the early observations to the left and the late to the right, so that a wave to the right means an undulation behind a wave more to the left.

It does not seem worth while making these variations the subject of a closer analysis. It would be necessary to develop the values in question in series with many terms and the results would be very problematic, as the observations are not sufficiently continuous. Important investigations might evidently be made by means of thermographs registering at different levels.

28. Causes of the Variations.

It has been repeatedly emphasized in the preceding sections that our observations are too incomplete for a satisfactory study of short-period variations in the sea. But although the discussion has to be hypothetical the observations and the calculations described in this chapter may be utilized for a preliminary judgment of the probable causes of such variations. The present lengthy treatment is justified only from the point of view of trying to attain a rational working hypothesis in a case where satisfactory observations do not exist at all. The only certain fact is that important variations in the vertical distribution of various elements sometimes do occur in the sea within short intervals of time.

As far as our observations and calculations go we may, then, make the following statements:

1. The variations in temperature are, to a great extent, of really periodic, diurnal and semi-diurnal, character. The diurnal variations below the surface in the deep sea are probably of a greater magnitude in proportion to the semi-diurnal, than they are in the rise and fall of the tides at the surface along the neighbouring coasts.
2. The phase of the variations is more or less variable from level to level at a fixed station.
3. The phase is more or less variable in a horizontal direction, even within fairly short distances.
4. The amplitudes of the variations are upon the whole independent of the vertical gradient of temperature (or the stability).

If correct, these statements lead to important conclusions with regard to the dynamics of the oscillations creating the variations. The oscillations may be caused by variations in the currents as well as by waves of different kinds. Before proceeding to a discussion of the various possibilities we must remember the following facts, already touched upon above (section 20):

In a sea with no currents, but with vertical variations in the physical properties, the isopycnal surfaces will form level surfaces, and the same thing will practically always be true of the isothermal and isohaline surfaces. This static equilibrium is disturbed when a current appears, and the more so the stronger the current is. Owing to the rotation of the earth (a Coriolis' force) the isopycnal, isothermal and isohaline surfaces then assume a slanting position, whereby a field of force (a "*solenoid field*") is created. The maximum obliquity of the said surfaces will appear in a section transversely to the direction of the current. On the other hand, a solenoid field formed primarily (for instance by local heating, or supply of river water) will create a current. It will take some time, but probably only a short period of some hours for a dynamic equilibrium to be established between the Coriolis' force and the solenoid forces. The latter will in some cases accelerate and in others retard variations in the currents.

α. Variations in the currents.

We shall here consider the convection (or gradient) currents and the tidal currents only, disregarding the pure wind-currents in the surface layers. To begin with we shall also leave out of account possible formations of internal waves as a result of vertical variations in the velocities of the currents, and will now only discuss the primary effect of the currents.

The convection currents may have different velocities and directions in different layers or at different stations, but if this state of things remains unaltered and is not subject to temporal variations, the horizontal and vertical distribution of densities (temperatures and salinities) will also remain constant except for other motions or agencies. Assuming that the convection currents are practically constant within a reasonable interval of time, we shall find no short-period oscillations created by them. The currents and the solenoid fields are subject to seasonal and annual changes, but the resulting horizontal and vertical variations in the physical elements have a much longer period than the variations now dealt with.

Our knowledge of the tidal currents has been greatly advanced by the observations of Professor SVERDRUP in the Polar Sea and the subsequent theoretical investigations by himself and Dr. J. E. FJELDSTAD. SVERDRUP has shown [1926] that the tidal currents at some distance from the shore must, on account of the rotation of the earth, be rotatory even if we have no interference of two or more crossing tidal waves. Quite close to the shore the tidal currents will go to and fro along a straight line, but further out these currents will go in ellipses with a decreasing excentricity as we proceed seawards. On account of the friction against the bottom the direction of the major axis of the ellipse as well as the maximum velocity and the time when the latter occurs (the phase) will vary from the surface to the bottom. In other words, the tidal cur-

rents have not the same direction nor the same velocity in the different layers at a given moment.

The tidal currents appear, whether a convection current exists or not, as a transport of water masses with velocities that vary periodically. In an area with no appreciable convection currents, *i. e.* where the isopycnal and isothermal surfaces are horizontal, the tidal currents will not materially affect the horizontal position, provided that the basin is so extensive that possible effects of pressing against a coast may be disregarded. The relative thickness of the water layers and their depth below the surface will then be maintained, and no appreciable vertical variations in the physical properties be observed as a primary effect of the water transport. But in the case of a strong convection current and, consequently, a marked sloping of the isopycnal surfaces, an appreciable effect may appear, *If the velocity of the tidal current is great in a direction transverse to the main direction of the convection current. the transport of water with the tides will make the sloping isopycnal, isothermal and isohaline surfaces move laterally for quite a long distance. Repeated series of observations at a fixed station within the domains of the convection current will then reveal considerable variations in the depth of, for instance, the isothermal surfaces.* This effect may easily be estimated when the tidal currents and the convection currents are known.

In order to illustrate the relations now discussed we shall assume that the convection current at Stat. 115 runs towards NE with a velocity of 30 cm./sec. at 200 metres, 20 cm./sec. at 300 m. and 10 cm./sec. at 400 m. The sloping of the isothermal, isohaline and isopycnal surfaces is then so steep, that a semi-diurnal tidal current at 300 metres needs only to have a mean component of velocity of less than 7 cm./sec. along the direction SE-NW in order to cause a variation in the observed depths of the said surfaces corresponding to the value of B found above (24 metres), the total distance measured along the horizontal between the extreme positions of the surfaces being about 3 kilometres.

This example shows that the transport of water by tidal currents, in an area with strong convection currents, may account for appreciable variations observed as "vertical" oscillations. The above-mentioned *variations in the orientation of the ellipses of the tidal currents, in the maximum velocities and the phases, will make such quasi-vertical oscillations alter in phase and magnitude from layer to layer downwards.* If the excentricity of the tidal ellipse is considerable, an orientation of the major axis in a direction forming a right angle to that of the convection current causes oscillations of temperature which are considerably greater than those observed if the major axis has the same direction as the convection current. The vertical variations in the tidal currents make the isothermal, isohaline and isopycnal surfaces alter their position not only by parallel movements, but also by some degree of twisting and by variations in the sloping of the surfaces. It is probable that the variations in phase and amplitude of the oscillations of temperature described in some of the preceding sections may to a great extent be accounted for in this way.

It follows from this discussion that the *vertical variations in the tidal currents create periodic variations in the intensity of a solenoid field,* as a result of the differences in the water transport. The deformation of the solenoid field must in its turn obviously affect the tidal currents, these being sometimes retarded and sometimes accelerated by the variations of the solenoid forces. But then the tidal wave itself will be influenced by a solenoid field, and the more so the stronger this field is. *The tidal waves and other waves will be somewhat deformed in a sea with appreciable variations of density, in comparison with waves in homogeneous water.* These questions have not yet been taken up for discussion, and we shall not enter more closely into them here.

From what has been said above it seems reasonable to assume that the oscillations of temperature observed at various fixed stations in the sea may to a great extent be accounted for by a horizontal transport of water with tidal currents. This corresponds to the result already deduced, *viz.* that the oscillations seem to have periods corresponding to tidal periods and to be most marked in those areas where the tidal currents as well as the convection currents may be assumed to be comparatively strong. All vertical oscillations with tidal periods are probably not accounted for in this way. They are evidently to some extent caused by sub-surface waves too.[1])

β. Boundary waves.

It is a well known fact that waves are created at the boundary between two strata of fluids with different densities when the strata move with different current-velocities. The theory of the boundary waves is based not only upon the assumption that there is a discontinuity at the boundary with regard to density as well as velocity, although the differences in both elements may be very small, but also that the two layers, above and below the discontinuity, are in themselves homogeneous. The speed of propagation of such waves is proportional to the square root of the

[1]) We have recently made numerous current-measurements in the Faeroe-Shetland Channel, the Norwegian Sea and the North Sea, in connection with observations for calculating the solenoid field and its variations. This vast material is now being arranged and will be discussed in a publication by Professor V. WALFRID EKMAN and the present author.

difference of density, while the amplitude is inversely proportional to the same square root. The velocity with which a boundary wave advances, is, according to HELMHOLTZ:

$$c = \sqrt{\frac{s_2 - s_1}{s_1} \cdot \frac{z_1 z_2}{z_1 + z_2} g} \text{ metres per second}$$

where s is the density (for sea water $s = 1 + 10^{-3} \sigma_t$), z the thickness (in metres) of the stratum of fluid, and g the acceleration of gravity (9·8). The index 1 indicates the upper stratum and 2 the lower.

The amplitude (half the vertical distance between the highest and lowest point of the wave) may, with sufficient accuracy, be expressed by the formula:

$$a = \frac{z_1 z_2}{z_1 + z_2} \frac{\triangle v}{c} = \triangle v \sqrt{\frac{s_1}{s_2 - s_1} \cdot \frac{z_1 z_2}{z_1 + z_2} \cdot \frac{1}{g}} \text{ metres,}$$

where $\triangle v$ is the difference of current velocity between the upper and lower strata (in metres per second).

From these formulae we see that the speed of propagation is independent of $\triangle v$, while the amplitude is directly proportional to this quantity. In other words: a boundary wave traverses a certain distance in a constant time as long as the density and the thickness of each stratum is unaltered, even if the current velocities are subject to variations in which case the amplitude varies. We see, further, that by $z_1 + z_2 =$ const. the speed of propagation as well as the amplitude have a maximum when $z_1 = z_2$, and decrease when the difference in thickness between the two layers increases.

Boundary waves are known from the dead-water phenomenon, owing to the thorough investigations by V. W. EKMAN. Dead-water occurs only where a water stratum with low densities rests on heavier sea-water, when the difference in density is very marked. It has been supposed that boundary waves may occur also in the open sea, where the differences in density are much less marked. A sudden gust of wind on the surface of the sea may, for instance, create such a wave at a boundary surface situated at some depth. Such boundary waves "generally occur singly, but periodical oscillations may be produced by a series of such waves, if the impulse creating them be regularly repeated at certain intervals of time. We consider it probable, for instance, that the tidal waves passing into a basin across a sub-oceanic ridge, like that between Scotland and Greenland, may give regular impulses such as these. It is even possible that the tidal waves may thus to some extent be transformed into boundary waves, which will advance with such reduced velocities" [HELLAND-HANSEN and NANSEN, 1909, p. 105].

The tidal wave coming directly from the North Atlantic into the Faeroe-Shetland Channel passes the Wyville Thomson Ridge. This ridge has a saddle depth of a little more than 550 metres, and its mean depth is 450—500 metres. During the "Michael Sars" Expedition no hydrographical stations were taken quite near the ridge. In May 1924 numerous stations were worked by Danish, Scottish and Norwegian research vessels in the Channel and neighbouring areas, amongst others on both sides of the Wyville Thomson Ridge. The observations exhibit great local variations and it makes a great difference which stations are selected for a comparison. A Norwegian station from May 12th, in 59° 36′ N and 6° 34′ W, bottom-depth 707 metres, was situated on the southern side of the ridge. To the north-west, on the other side of the ridge, a Danish station was taken on May 6th, in 59° 59′ N and 6° 7′ W, bottom-depth 650 metres. The observations (published in Bulletin Hydrographique for 1924, with Appendix) gave:

	Norwegian Station			Danish Station		
	t °C	S ‰	σ_t	t °C	S ‰	σ_t
400 metres	8·81	35·33	27·42	8·34	35·32	27·49
500 „	·79	·33	·42	6·04	·17	·71
600*) „	·78	·33	·42	3·90	·03	·84

The effect of the ridge in shutting off the warm water from the Atlantic at depths below 400—500 metres is very conspicuous. On the northern side the density increases rapidly downwards from 400 to 600 metres, while it is practically constant at the southern side.

The tidal wave passing the ridge gives rise to quite strong tidal currents in the southern part of the Faeroe-Shetland Channel down to the level of the ridge. There is, in all probability, a marked decrease in the velocity of the tidal currents at this level. It is impossible to calculate in a satisfactory way the amplitude and speed of propagation of boundary waves which may be formed in these circumstances, for we have no observations of the tidal currents at the depths in question and, moreover, have not to deal with two homogeneous strata with a real discontinuity at the boundary between them. The transitions in density are quite continuous, but the rate of the vertical variations differs at different levels. For a rough approximation we may, however, employ the formulae given above and use the Danish observations quoted,

*) The Norwegian observations were actually taken at 650 metres, which in this case makes no difference.

taking $s_1 = 1{\cdot}02749$, $s_2 = 1{\cdot}02771$, $z_1 = z_2 = 400$ metres (the bottom-depth a short distance N of the station is 800 metres). We then obtain:

$$c = 0{\cdot}65 \text{ metres per second}$$

and $$2\,a = 618 \triangle v \text{ metres}$$

If, for instance, $\triangle v$ be taken as equal to 0·1 m/sec. this computation gives a boundary wave with a height of more than 60 metres from crest to through, advancing at a speed of 1·3 knots. This would mean oscillations of the same order of magnitude as we have found by the harmonic analysis of our observations of temperature.

If we have two layers, each homogeneous with a discontinuity at the boundary, the amplitude of the oscillations decreases upwards as well as downwards from the boundary, the phase along one and the same vertical having everywhere a definite value $k°$ or $k° + 180°$. In stratified water the conditions are altered in several respects, and further complications arise when the upper edge of the ridge is not horizontal, but slopes so that boundary waves may be created at different levels in different parts of the ridge. With our present knowledge it is impossible to make even a fairly trustworthy computation of the system of boundary waves which may occur in the Faeroe-Shetland Channel.

Boundary waves created at the Wyville Thomson Ridge will probably take some days in reaching the places where the "Michael Sars" station 115 and the Scottish station were taken. The waves would probably appear especially at 300—400 metres' depth at Stat. 115 and at 400—500 metres at Stat. Sc., provided that the waves were substantially confined to the water layers in which they were originally created. On this assumption we should then have a marked decrease of amplitude upwards and downwards from these levels, with a certain constancy of phase. This does not seem to correspond with our results as regards the temperature variations with tidal periods. It must be noted that the waves are damped on the way, so the amplitudes decrease if the difference of density ($s_2 - s_1$) is maintained.

We may certainly expect to find boundary waves in some parts of the sea, such as the Faeroe-Shetland Channel, and it is probable that some of the observed temperature-variations with tidal periods, as well as some of the residual variations, are caused by such waves. In my opinion most of the periodic temperature variations found at Stats. 115 and Sc. are, however, due to horizontal displacements by tidal currents. The mixed effect of tidal currents on the spot and boundary waves makes the variability within such a sea-area all the greater.

γ. *Stationary waves.*

It has been suggested that stationary waves (standing waves) may occur in the sea in such a way that perceptible vertical oscillations may arise. In the case of stationary waves the vertical amplitude is nil at the nodal line and increases to a maximum at a horizontal distance from the node of $^1/_4$ of the wave length. Between two nodal lines, or in one half of the basin in case of a uninodal oscillation, the phase is exactly the same in all places and depths, and exactly 180° different from the phase at the other side of the node. It is readily seen that the variations of temperature observed in the Faeroe-Shetland Channel cannot be explained by ordinary waves of this kind, possibly with the exception of a few of the residual variations.

A special kind of stationary waves may arise when boundary waves are reflected on reaching the slope of the sea-bottom in such a way that an interference between the primary waves and the reflected occurs. As an example of such stationary waves may be given the internal seiches (or "temperature seiches") observed, for instance, in Scottish lochs and studied by E. M. WEDDERBURN. Provided that possible boundary waves in the Faeroe-Shetland Channel are created at the Wyville Thomson Ridge and, like the tidal wave, proceed N. E. in the direction of the Channel, the reflection will probably be of but subordinate importance in this area, even if some reflection takes place.

Boundary waves casually created by transient atmospheric disturbances may be transformed into internal seiches, in which case the period of oscillation would depend upon the extension of the sea basin and only rarely coincide with the tidal periods, while the phase should be the same everywhere between the nodal lines.—

Vertical oscillations of the water layers, whether due to really vertical motions or to horizontal displacements, are of great interest in several respects. The problem is in itself important for our understanding of what is taking place within the huge water-masses of the Ocean, and further investigations by means of detailed observations may even lead to progress in general hydrodynamics. For physical oceanography such studies will be of great significance if the question of the representative quality of ordinary oceanographic observations (cf. section 19) be thereby more definitely established than is now the case. It is also worth mentioning here, that the problem of vertical oscillations has a bearing upon some questions in marine biology and fisheries. Short-period variations in the distribution of the water layers with such amplitudes as may possibly come to light, may perceptibly affect the local occurrence of plankton, and in that case perhaps of fish-shoals as well.

A detailed investigation of the oscillations in question cannot properly be carried out unless observations are made at several stations simultaneously. The close co-operation of several vessels is therefore necessary, and continuous observations of the vertical distribution of temperature and density ought to be made in connection with direct current-measurements, while at the same time sufficient material for a detailed representation of the solenoid field and its variations should be secured. This seems a task worthy of international co-operation.

VI. THE TEMPERATURES IN THE SEA.

29. Gain and Loss of Heat.

The heating of the sea as a whole is almost exclusively due to absorption of radiating heat from sun and sky. The quantity of heat radiation penetrating the surface of the sea has an order of magnitude of 10^5 gram calories per year per square centimetre of the surface. A heating of the surface merely by contact with warmer air is of comparatively small importance (cf. section 11). Some heat from the interior of the earth is conveyed to the sea, but ti only amounts to between 50 and 80 g. cal. per year per cm.^{2} of the bottom. Heating by transformation of kinetic energy or by chemical processes is also of quite a subordinate importance compared with the first-named source of heat.

The cooling of the sea takes place exclusively from the surface. It is to a great extent caused by emission of dark heat rays. In some regions the evaporation is very considerable and deprives the sea of great quantities of heat which is transferred to the atmosphere as latent heat of the water vapour and is liberated when the vapour is condensed. Contact with colder air (convection) also causes a sinking of the temperature of the sea.

When we consider the sea as a whole and regard the most important factors only, the total loss of heat due to emission, evaporation and convection must, on an average, be equal to the gain of heat by absorption of radiating energy. There are, however, great local and temporal changes in the relation between the different factors. Within a limited region regular periodic (daily and seasonal) variations in this relation may be considerable, but irregular meteorologic variations in cloudiness, wind, humidity etc. may, also, have a great effect upon the temperature of the sea. It would be difficult to unravel the temperature conditions in the sea even if this be motionless, but it is still much more so on account of currents and turbulent motions.

We shall, here, only attempt to make an approximate estimation of the relation between the various quantities of heat which are of greatest importance as to the exchange of heat to and from the ocean in general. To begin with, we shall consider an area-element of the surface along a meridian from 70° N to 70° S and estimate the average quantities of heat gained and lost per square centimetre of this element. By Q_1 we denote the average quantity of heat gained by absorption of sun rays coming directly and as diffuse radiation reflected from the atmosphere and the clouds. The heat consumed by evaporation may be termed Q_2, that lost by excess outwards of long-wave radiation Q_3, and heat lost by convection to the atmosphere Q_4. Leaving other processes out of account, we have:

$$Q_1 = Q_2 + Q_3 + Q_4$$

The radiation from the sun reaching the outer part of the atmosphere of our globe corresponds to 2 g. cal./cm.^{2} min. (the "solar constant"). Some of this radiation is reflected to space again and is lost for the heating of the earth and its atmosphere. The greater portion is partly absorbed by the atmosphere, and the rest reaches the sea or the solid crust of the earth. The amount of heat which is absorbed by the sea from the direct sun-rays depends upon the altitude of the sun and the transmissibility of the atmosphere. It is subjected to great variations. To this direct radiation from the sun we have to add the diffuse radiation from the atmosphere (about 8 per cent of the direct radiation from the sun, according to L. V. KING) and the clouds during the hours of daylight. On the other hand, about 17 per cent of the total radiation falling upon the surface of the sea is reflected again [W. SCHMIDT, 1915]. Starting from data compiled by KIMBALL, we find as an average for the above-mentioned area-element from 70° N to 70° S in the Atlantic:

$$Q_1 = 275 \text{ g. cal./cm.}^2 \text{ 24 hours.}$$

G. WÜST [1920] has made a careful study of the evaporation from the sea. He has calculated the mean evaporation in mm. per 24 hours within zones comprising 10° of latitude. From WÜST's data we may find the corresponding quantities of heat, and we obtain the following value as an average for our area-element:

$$Q_2 = 120 \text{ g. cal./cm.}^2 \text{ 24 hours.}$$

In other words, about 44 % of the quantity of heat absorbed in the sea by the direct and the diffuse solar radiation is consumed by the evaporation.

The sea may be regarded as a nearly "black body". According to STEFAN's law the radiation outward, E, is proportional to the fourth power of the absolute temperature (T) of the body:

$$E = k\, T^4,$$

k being a constant which for a perfectly black body is equal to $1{\cdot}28 \times 10^{-12}$, when the radiation is calculated in gram calories per second per square centimetre of the surface. This radiation is 15 *per cent* greater at 10° C and 33 *per cent* greater at 20° C than at 0° C.

On the other hand, heat radiates from the air to the sea. As the temperature of the air generally is lower than that of the sea, the dark heat radiation from the air to the sea is, on an average, smaller than the corresponding radiation the other way. By using the indices s and a for sea and air respectively, we have:

$$Q_3 = Q_s - Q_a = k_s\, T_s{}^4 - k_a\, T_a{}^4.$$

On account of reflection, the intensity of the radiation from the very surface of the sea is reduced in such a way that k_s may be put equal to $0{\cdot}83 \times k \times 86400 = 918 \times 10^{-10}$ when we calculate the radiation for 24 hours. The factor 0·83 is computed by W. SCHMIDT [1915].

k_a is a constant not very different from k_s, but T_a is a variable quantity, as the radiation from the atmosphere to the sea takes place up to high levels, varying with cloudiness, humidity etc. Q_a is, therefore, difficult to calculate directly.

The effective radiation Q_3 from the surface of the sea outwards may, however, with sufficient approximation be computed from observations of the nocturnal radiation made by means of a black-bulb thermometer [ÅNGSTRÖM, 1915; DORNO, 1919]. Considering the variations in cloudiness, we find the effective radiation between 70° N and 70° S to be on average equal to 0·78 g. cal./cm.² min., or

$$Q_3 = 112 \text{ g. cal./cm.}^2 \text{ 24 hours.}$$

The effective radiation outward from the sea corresponds to about 41 % of the quantity of heat gained by the direct and the diffuse solar radiation.

We have:

$$Q_4 = 275 - 120 - 112 = 43 \text{ g. cal./cm.}^2 \text{ 24 hours.}$$

W. SCHMIDT [1915] has calculated the quantities of heat (w) which are at disposal for the evaporation (v) and the convection from the sea to the atmosphere. He has, further, calculated the ratio v/w, and found it to be 0·63 on an average between 70° N and 70° S. This gives $Q_4 = 0{\cdot}37\, Q_2 = 44$ g. cal./cm.² 24 hours, or practically the same value as found above.

The above calculations do not claim to give more than an estimation of the relative importance of the various causes for the loss of heat from the sea in general. The result is, then, that *among these causes the evaporation is the most powerful one. Second to the evaporation in importance comes the excess outward radiation of dark heat,* called Q_3 above, *and finally the direct convection of heat to the atmosphere.* By the two latter processes the heat is given off to the air directly above the sea, while the latent heat of the water vapour may be liberated far away from the places of evaporation.

These results refer to the average conditions only. There are many variations in the quantitative relation between the said agencies. It depends upon the actual conditions in the atmosphere (humidity, stability, cloudiness, wind etc.) and the absolute temperature of the sea surface as well as of the air. We shall, however, not go further into these questions here.

30. Absorption of Heat in the Sea.

In the previous section it was stated that the average quantity of heat (Q_1), absorbed by the sea from direct and diffuse solar radiation amounted to about 275 g. cal./cm² 24 hours. The heat rays in question are of different wavelengths, and the heat energy of the rays varies with the wave length, as is well known. Generally speaking, this energy increases from the extreme point of the very long infra-red part of the spectrum towards the small visible part of it and still a little further, attaining a maximum in red at a wave length of about 0·00065 mm. $= 0{\cdot}65\,\mu$. Then it decreases quickly towards the blue and violet part of the spectrum and is very small in the ultraviolet part. Summing up the heat energy of various parts of the spectrum we find that about 60 % of the total heat energy of the normal spectrum (at sea level) is due to the dark rays and about 40 % to the visible, assuming that the sun is at medium height [DORNO, 1919].

If the solar radiation that penetrates the water and is absorbed there has an initial intensity I_0, it will acquire, after having passed through a length L of the water, a reduced intensity, which may be found by the formula:

$$I_L = I_0\, e^{-\varepsilon L}$$

where $e = 2{\cdot}71828$ and $\varepsilon =$ a quantity generally called the coefficient of absorption (or coefficient of extinction). ε may be defined as the reciprocal value of the way which the rays must go in the absorbing medium in order to have their intensity reduced to $1/e$ of the initial value.

ε varies greatly with the wave length of the rays. When we have pure distilled water and L in the formula above is reckoned in metres, ε is 0·01 — 0·02 for blue and green rays at wave lengths between 0·45 and 0·54 μ, 0·3 for red rays at about 0·65 μ and 2·0 for dark rays at $\lambda = 0{\cdot}8\,\mu$, increasing very much with greater wave lengths.

The conditions in sea-water are little known yet, but the coefficients of absorption are not very different from those found for distilled water. The greater part of the heat rays are absorbed in the uppermost layer of water. Only a very small fraction of the dark heat rays reaches as far down as one metre below the surface without being absorbed. The intensity of red rays of a wave length of about 0·65 μ is reduced to 1 *per cent* after having passed through some 15 metres of water, and to 1 *per mille* after some 30 metres. The intensity of the green rays is less than that of the red rays at the surface, but already at a depth of some metres the ratio is, in most cases, probably reversed.

By some preliminary investigations with a photometer constructed by the present writer it was found, during the "Michael Sars" expedition, that the transparent waters between the Canary Islands and the Sargasso Sea contained many of the visible rays at 100 metres, the intensity being greater in the blue and green part of the spectrum than in the red. At 500 metres below the surface the intensity of the red rays seemed to be very small while that of the blue rays was quite appreciable (exposure with Wratten and Wainwright gelatine colour filters for 40 minutes in the middle of the day). Even at 1000 metres the photographic plate (without colour filters) was blackened after having been exposed for 80 minutes. Some radiation reaches even the greatest depths of the ocean, but here the intensity is so minute that it escapes observation even if the effect be accumulated (as in the case of photographic exposure) for a very long time.

By some experiments in shallow Danish waters KNUDSEN found [1923] a minimum of the coefficient of absorption in the green part of the spectrum and not in the blue, which is probably to be explained by the occurrence of different kinds of solid particles in the water. Colloids as well as coarser suspensions and microscopic organisms may hinder the passage of the rays very appreciably and cause another selective absorption than found in optically pure water.[1])

The absorption of the radiation from the sun directly and from the sky causes a heating of the water to some distance below the surface. We may easily obtain an approximate estimation of this effect on the temperatures in the ocean.

From LANGLEY's well-known curve illustrating the distribution of energy (in the form of heat) throughout the normal spectrum we may interpolate relative values of the heat energy of the radiation reaching the surface of the sea. We have done this for intervals of wave-lengths corresponding to 0·025 μ. ASCHKINASS and others have determined the coefficients of absorption (ε) for various wave-lengths in pure distilled water. From these data the values of ε wanted have been found directly or by linear interpolation, with sufficient approximation. By means of the formula given above we may, then, compute the absorption of heat per metre for different wave-lengths and by numerical integration find the total absorption. The computations give:

$$I_0 - I_1 = 0{\cdot}71\ I_0$$
$$I_{50} - I_{51} = 0{\cdot}0012\ I_0$$
$$I_{100} - I_{101} = 0{\cdot}0004\ I_0$$

The indices correspond to L, *i. e.* the distance passed by the rays through the water. It has been supposed to be the same for all wave-lengths. It does not correspond to the depth m below the surface of the sea unless the rays hit the surface vertically (the sun in zenith). When the sun is just above the horizon the direct sun-rays penetrating the sea are refracted so much that their direction forms an angle β of about 42° with the surface. In this case m is equal to 0·67 L. When the sun is 60° above the horizon, we have $\beta = 68°$ and $m = 0{\cdot}93\ L$.

The value of I_0 is very variable. It depends upon the position of the sun above the horizon, cloudiness, humidity etc. As a probable mean value we may put I_0 equal to 360 gr. cal. per day per square centimetre of the sea surface of the North Atlantic in summer. Allowing for the deviations of the rays' directions from the vertical we obtain the following results:

In the uppermost metre of the sea so much heat (about 70 *per cent* of the total heat energy) is absorbed by the radiation from sun and sky that the temperature of the water on an average would rise about 2—3° C per day. The increase of temperature is very much less because heat is lost by evaporation and radiation from the surface. Wave motion will diminish the effect in

[1]) In this connection an effect of the radiation upon organisms living in the upper strata of the sea may be worth mentioning. To what extent such organisms will feel a heating above the temperature of the surrounding water depends partly upon their capacity of reflecting or absorbing heat rays. If the body of a living creature has the character of a "black body", in the physical sense of the word, the sensation of heating in the day may possibly be quite distinctly felt. It is perhaps not excluded that some of the vertical movements of animal organisms — downwards in the day and upwards at night — may partly be due to the stimulus of heating and not only to a reaction against variations in the intensity of light or to the chemical activity of the radiation.

the uppermost layer of water and cause a greater rise of the temperature at, for instance, 5 or 10 metres than would have been found when no waves stirred the water. In section 32 we shall discuss the seasonal variations of temperature. It may, now, just be mentioned that the mean rise of temperature at the greater part of the surface of the North Atlantic between 25° and 50° N. Lat. from February to August amounts to 5°—8° C. or around 0·04° C per 24 hours as an average for the whole epoch.

Our computations show that the temperature at 50 metres in spring and summer on an average rises about 0·004° C per day as a result of the absorption at this depth of radiation from sun and sky. It corresponds to an increase of about 0·7° C from April to September. The corresponding rise of temperature at 100 metres below the surface is on an average about 0·0013° C per day or 0·2° C from April to September.

Absorption of heat radiation from sun and sky goes on in the great oceans every day all the year round. The visible rays cause a heating (however slow) quite far down below the surface. The water itself only radiates dark heat-rays with a very great value of ε. This radiation is included in the molecular conductivity of heat which has been determined by experiments and found to be exceedingly small in water. Practically speaking, the heat once given to the water at, say, 100 metres' depth by radiation from above will not escape again in the form of radiation unless the water comes to the surface. It would be retained and the effect be accumulated so that the temperature always would be on the increase if the heat were not taken away by convective processes such as turbulence and currents.

31. Conduction of Heat.

We shall here only discuss the vertical conduction of heat and not the transport of heat by currents.

In water which is perfectly motionless heat from above will propagate downwards at an exceedingly slow rate. The coefficient of molecular heat conduction is so small that temperature variations due to such conduction may be perfectly ignored in most cases as far as the ocean is concerned.

If the water is in motion (waves and currents) the water particles generally will acquire disordered movements in many directions. This phenomenon is called turbulence. We shall, for the sake of argument, assume that we have a horizontal current with velocities that decrease from level to level downwards. Many water particles which at a given moment are found at a certain level will shoot away from it in various directions, up and down, and not move parallel to the main direction of the current. They may return to the first level again, and perhaps continue further to the opposite side. The average length of the vertical distances traversed by all the particles depends chiefly upon the velocity of the current and the vertical stability of the water layers. On the assumption made, the water particles will, when shooting upwards, upon the whole get a slightly increased velocity in horizontal direction corresponding to the difference in current velocity between the two levels, but at the same time reduce the current velocity at the upper level. The opposite effects are caused by the water particles shooting downwards. These variations in horizontal velocity are obviously effected momentarily. The process is of great dynamic significance; it leads to the notion of "turbulent friction" or "turbulent viscosity", and a "virtual coefficient of friction" which is different from the ordinary coefficient of molecular viscosity.

Now the water particles take their physical and chemical properties with them when moving from one level to another, so also their contents of heat. By the turbulent motion an exchange of heat between the different levels must take place, but we may *a priori* presume that this effect requires a longer time than the corresponding dynamic effect to be fully established [cf. J. P. JACOBSEN, 1913, p. 71]. We may speak of a "virtual coefficient of heat conductivity" which is much larger than the coefficient of molecular conductivity of heat, but probably numerically smaller than the corresponding coefficient of friction.

Processes such as these take place nearly always when a current appears in the sea. The turbulent motion generally becomes more and more vivid the quicker the current flows. In homogeneous water disordered motion may easily arise and the mean vertical transfer of the water particles from their original place be very appreciable. The latter is reduced in water where a stable equilibrium exists and the more so the greater the stability is. In marked discontinuity layers (cf. section 20) the single water particles will not move up and down in turbulent motion to any noteworthy extent. Such a layer forms a very great obstacle to vertical displacements by turbulence and, therefore, prevents or at any rate very materially reduces an interchange of water from both sides.

Thus, the virtual conduction of heat is also relatively great in water with small vertical gradients of density. Supposing that the density chiefly depends upon the temperature (the salinity nearly constant) we must find less turbulence by great vertical gradients of temperature than by small. But at the same time a small vertical motion of the particles in water with great vertical variations in temperature may have just as great or greater effect on

the temperature than a larger vertical motion in water with smaller gradients.

Unit variation in temperature has a much greater effect upon density at high temperatures than at low. A variation of 0·1° C at temperatures about 0° C causes a variation of 0·5 in the second decimal place of σ_t, while

$$10 \frac{\partial \sigma}{\partial t} = 1{\cdot}7 \text{ at } t = 10° \text{ C, and } = 2{\cdot}6 \text{ at } t = 20° \text{ C}$$

(calculated for sea-water of 35 ‰ salinity). The corresponding variations in stability are, approximately, 5, 17 and 26 units of $10^8 E$. In other words: a variation of 0·1° C changes the stability 5 times as much at 20° C as at zero. As variations in density act against the disordered motions, these are more hampered at high temperatures than at low as far as this special effect of changes in temperature is concerned. But on the other hand the internal friction (the molecular viscosity) decreases by increasing temperatures. The coefficient of internal friction in sea-water of 35 ‰ is about 0·019 (C. G. S. units) at 0° C, 0·014 at 10° C and 0·010 at 20° C. This means that the resistance against the movement of a particle amongst the other water particles is less at higher temperatures than at lower. The problem is still more complicated because the forces which generate the turbulent motion are influenced by the internal friction. Without entering further into these questions here we may only state that the virtual conduction of heat depends upon the absolute temperature as well as on the vertical variations of temperature (the first and second derivates with regard to depth).

In the sea we have also variations in salinity which have a great effect upon the vertical distribution of density and, consequently, upon the stability. In most parts of the North Atlantic the salinity decreases from the surface downwards just as the temperatures do. By the combined effect of temperature and salinity we may, then, have comparatively small vertical variations of density in proportion to the variations in temperature. In this case a certain energy of the turbulence causes a quicker conduction of heat than in fresh water (or in sea-water of constant salinity) with the same distribution of temperature. In regions with Arctic water of low salinity at the surface the vertical gradient of salinity is negative (reckoned downwards) and the stability correspondingly augmented. The distribution of salinity regarded separately will here counteract the virtual conduction of heat.

When the surface layers are strongly heated in summer the stability becomes very marked, notwithstanding the increase of salinity on account of evaporation. The convection of heat to lower levels is then much hindered, which explains that the water-masses below the surface layers are so very little heated from above in the tropics. Heavy wave motion at the surface causes a perfect mixing only of the upper 10 to 20 metres or a little more.

A surface current going towards lower latitudes generally becomes more and more heated at the surface, because the effect of the radiation from sun and sky exceeds the heat lost by outward radiation and by evaporation. Then the stability becomes more and more pronounced, while the virtual conduction of heat downwards is lessened. We arrive at the paradoxal result that *the water-masses below the surface layers are the more "protected" against heating the stronger the heating at the surface is.* It is, then, supposed that concentration by evaporation does not keep pace with the increase of temperature to such a degree that the stability remains constant.

A surface current flowing towards higher latitudes becomes gradually cooled, so that the stability is diminished and the vertical convection facilitated. Heavy waves created by a strong wind make turbulence, and, consequently, vertical heat convection appear deeper in this case than when the surface is warmer and the stability accordingly greater.

Such variations of temperature with time that are solely due to the vertical conduction of heat, may be expressed by the following equation (which is analogous to the equation representing the acceleration of the frictional force in hydrodynamics):

$$\frac{\partial \tau}{\partial t} = \nu \frac{\partial^2 \tau}{\partial z^2} + \frac{\partial \nu}{\partial z} \frac{\partial \tau}{\partial z},$$

where τ means temperature, t time, ν virtual coefficient of temperature conductivity, and z depth. By means of this equation we may draw some general conclusions as to the variations in temperature at the depth z. It makes, however, a great difficulty that we know so very little about the variations of ν. As mentioned above, the turbulence depends upon several factors, especially the current velocities $\left(u \text{ and } \frac{\partial u}{\partial z}\right)$ and the stability (E). The exact quantitative relationship between these values and the turbulence is as yet unsettled.

To begin with, we shall assume that the temperature decreases downwards as is generally the case in the sea. We may then examine separately the variations in temperature according as $\frac{\partial^2 \tau}{\partial z^2}$ is negative, nought or positive (cf. Fig. 6). ν is always reckoned positive.

I. $$\frac{\partial^2 \tau}{\partial z^2} < 0.$$

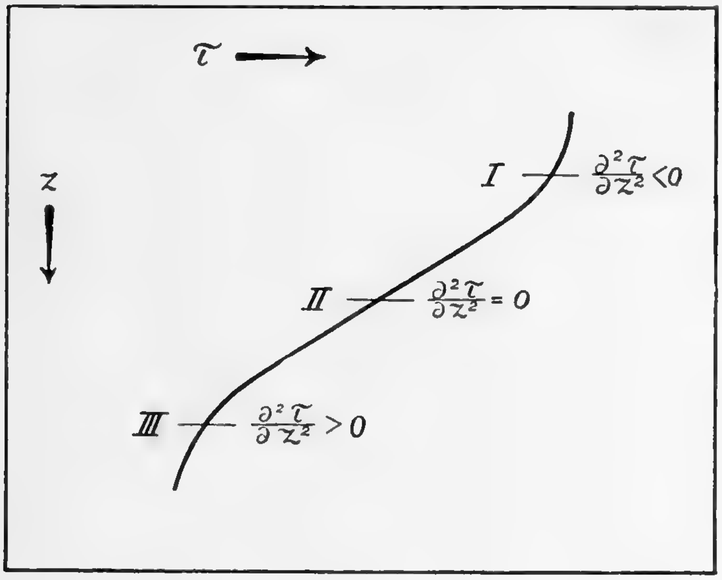


Fig. 6. Variations in the vertical gradient of temperature, the temperature decreasing downwards.

This case is very common in the upper water-layers especially in spring and summer. If ν is constant in vertical direction $\left(\frac{\partial \nu}{\partial z} = 0\right)$ the temperature obviously decreases. We may, however, presume that in many, or probably most, cases with the supposed distribution of temperature the velocity of the current decreases with the depth, while the stability increases. Under these circumstances we must expect that ν decreases, so that the product $\frac{\partial \nu}{\partial z} \cdot \frac{\partial \tau}{\partial z}$ becomes positive. Then the temperature rises, remains constant or falls according as

$$\left| \nu \frac{\partial^2 \tau}{\partial z^2} \right| \lesseqgtr \left| \frac{\partial \nu}{\partial z} \frac{\partial \tau}{\partial z} \right|.$$

The temperature sinks when $\frac{\partial \nu}{\partial z} > 0$, which may probably happen if $\frac{\partial u}{\partial z} > 0$

$$\text{and } \frac{\partial E}{\partial z} \left(\text{or, practically, } \frac{\partial^2 \sigma}{\partial z^2}\right) > 0.$$

II. $$\frac{\partial^2 \tau}{\partial z^2} = 0.$$

A vertical distribution of temperature with practically constant variations with depth is often met with, especially in intermediate water-layers. If ν is constant no rise or fall of temperature takes place. If ν varies, the sign of $\frac{\partial \nu}{\partial z}$ determines which way the temperature variations go. The temperature rises if ν decreases with depth, and *vice versa*.

III. $$\frac{\partial^2 \tau}{\partial z^2} > 0.$$

Such a distribution of temperature is found at the upper limit of the deep water, and in summer also at high levels below the heated surface-waters. The analysis lead to results opposite to those deduced above in example I.

The conditions in quasi-discontinuity layers may be worthy of a special mentioning. Fig. 7 demonstrates the vertical distribution of temperature at two stations SW of Ireland, *viz.* the "Michael Sars" station 92 from July 23rd, 1910, and the "Thor" station 280 from September 3rd, 1906. The latter station was situated 10 naut. miles to the south of the former. The distribution of temperature is represented by isotherms for every degree centigrade from the surface to 400 metres. Allowing for local

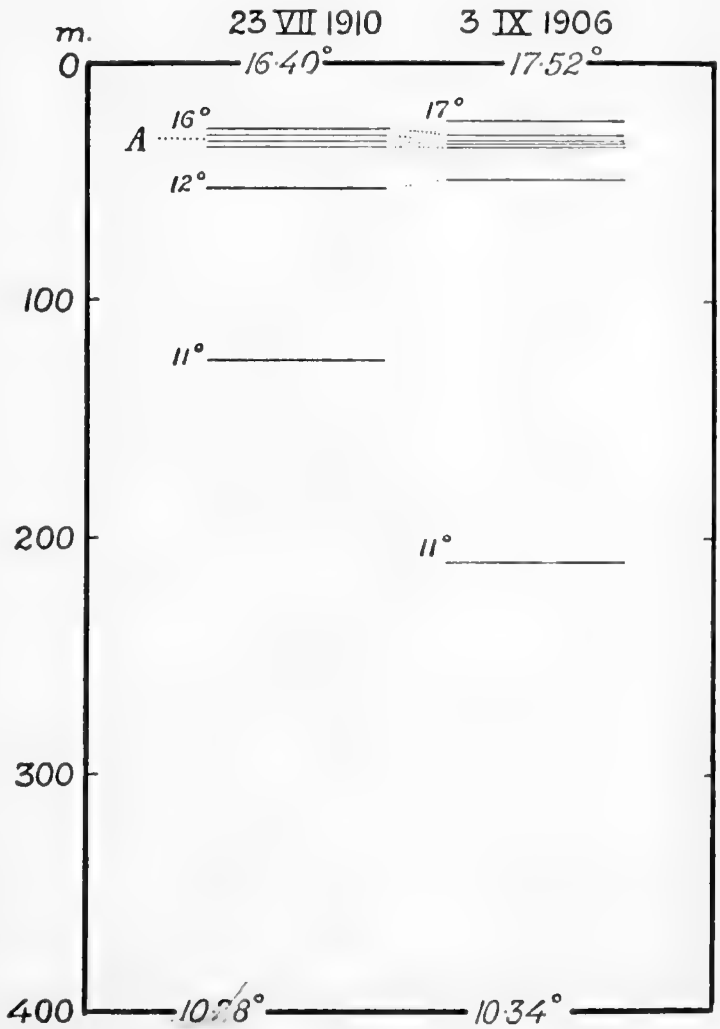


Fig. 7. The vertical distribution of temperature at the "Michael Sars" station 92 (23. VII. 1910) and the "Thor" station 180 (3. IX. 1906). Isotherms are drawn for each whole degree centigrade between the surface and 400 metres.

and other differences between the stations we may only call attention to the fact that in both cases the isotherms are crowded below 25 metres, indicating a quasi discontinuity. We have, here, in quick succession all three cases mentioned above. Such sharp vertical transitions of temperature (and density) are in summer often found over wide areas just below the warm surface-layers. In the open ocean with comparatively small vertical variations in salinity, the stability has then a maximum where $\left|\frac{\partial \tau}{\partial z}\right|$ has a maximum. At Stat. 92, Fig. 7, it corresponds to the depth marked "A"; at the other station it is situated a little deeper. At levels above this depth the distribution of temperature corresponds to our case I. We have $\frac{\partial E}{\partial z} > 0$, which tends to make ν decrease downwards as far as "A". Near this level $\frac{\partial^2 \tau}{\partial z^2}$ approaches 0, and it is nought at the level itself (case II). The surface waters when stirred by wind are the seat of a vivid turbulent motion, but it is a matter of course that the energy of this turbulence decreases downwards. In fresh wind we must expect that ν decreases fairly rapidly with depth, just above the level of "A", with the result that a considerable rise of temperature takes place. Below this level the conditions correspond to those in our example III. The stability decreases rapidly. At these depths the turbulence due to wind directly is but small (if it occurs at all). On the other hand, the vertical variations in the velocity of the currents may be considerable, to judge from dynamical calculations. It is most likely that $\frac{\partial \nu}{\partial z}$ is positive, and therefore, $\frac{\partial \nu}{\partial z}\frac{\partial \tau}{\partial z}$ negative. Then the temperature below "A" sinks or rises according as $\left|\nu \frac{\partial^2 \tau}{\partial z^2}\right| \lessgtr \left|\frac{\partial \nu}{\partial z}\frac{\partial \tau}{\partial z}\right|$. But even if it rises, the value of $\frac{\partial \tau}{\partial t}$ may probably in many cases be smaller than the corresponding value for the water just above "A". In such cases the discontinuity layer must be intensified, and at the same time its vertical thickness often increases.

We have hitherto dealt with the most common case that the temperature decreases downwards. In some instances the temperature may increase with depth $\left(\frac{\partial \tau}{\partial z} > 0\right)$. The salinity must, then, increase with depth too $\left(\frac{\partial S}{\partial z} > 0\right)$, as a state of instability cannot exist in any noteworthy degree. Sometimes we find a minimum or a maximum of temperature at an intermediate depth, the vertical gradient of temperature having different signs above and below this depth. Such a distribution of temperature is met with, for instance, at the Newfoundland Banks and, at larger depths, in those parts of the eastern North Atlantic where water from the Mediterranean is specially prominent.

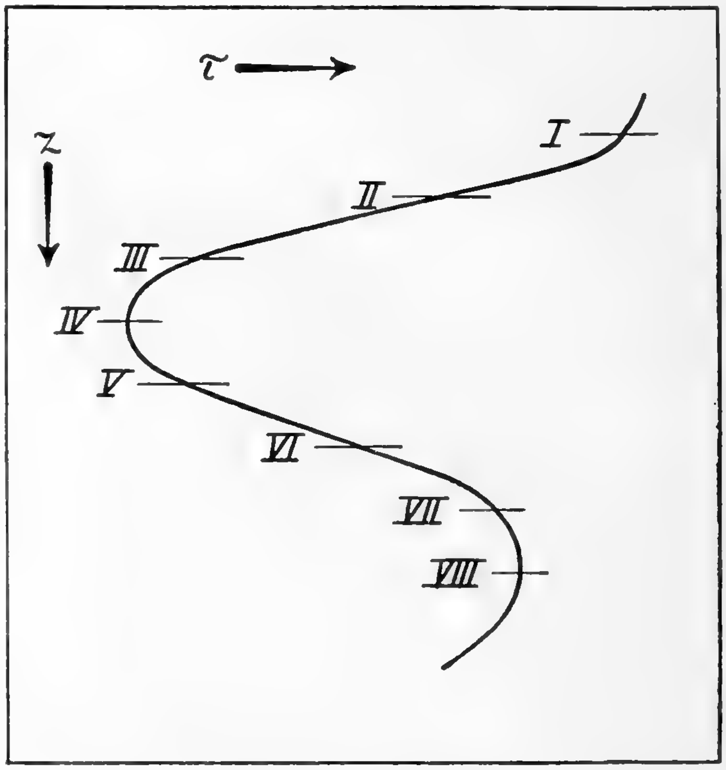


Fig. 8. Schematic illustration of different kinds of variation in the vertical distribution of temperature.

Fig. 8 demonstrates the different cases to be encountered, with regard to the vertical variations of temperature. We obtain the following scheme, referring to our initial equation:

	$\frac{\partial \tau}{\partial z}$	$\frac{\partial^2 \tau}{\partial z^2}$	$\frac{\partial \tau}{\partial t}$
I.	negative	negative	?
II.	negative	0	?
III.	negative	positive	?
IV.	0	positive	positive
V.	positive	positive	?
VI.	positive	0	?
VII.	positive	negative	?
VIII.	0	negative	negative

Intermediate minima or maxima of temperature will gradually vanish if they are not renewed by horizontal

currents. In the other cases included in the above scheme the variation of temperature with time is unsettled as long as the value of $\frac{\partial \nu}{\partial z}$ is unknown. If ν is constant with regard to depth we find that the temperature rises in the cases III and V, while in the cases I and VII it sinks. If ν decreases with depth the temperature rises in case II and sinks in case VI, while the opposite variation of temperature takes place if ν increases with depth.

From what is said above it is evident that such variations of temperature which are due to a virtual conduction of heat vertically, depend upon the energy of turbulence and, therefore, on the velocity of the horizontal currents and its variations with depth. As the currents bring various amounts of heat with them, the variations of temperature owing to vertical conduction are interwoven with the variations caused by the horizontal flow of heat. In some cases a lifting or sinking of large water-masses complicate the conditions.

32. Seasonal Variations.

Synoptic charts like those now constructed every-day for meteorological purposes can not be obtained from the ocean. When we disregard short-period oscillations (chapter V), a small area may, however, be examined by one ship within so short a time that other temporal variations may be neglected. An examination of larger regions as, for instance, the eastern North Atlantic, within a short space of time, would require a whole fleet of ships in cooperation. If we wish to construct temperature charts for the ocean we are at present obliged to utilize observations from many single expeditions which have worked in different seasons and years. A discussion of seasonal and annual variations is important in order to find means for reducing all observations to a common epoch.

The temporal variations of temperature may be regarded from two different points of view. We may either investigate the, so to say individual, variations within characteristic water masses, accounting for possible local displacements. In this case we may speak of investigations according to "oceanographic co-ordinates". Or, we may study the changes according to ordinary geographic coordinates. In the latter case we get a combination of thermal variations in the individual water masses and changes which are due to displacements of the currents.

Seasonal variations in the distribution of currents are known from different localities. The conditions in the Norwegian Sea present a characteristic example. The coastal water which moves along the Norwegian coast, between this and the Atlantic current in the Norwegian Sea, exhibit marked seasonal changes in temperature and salinity so that the interior field of force varies with the seasons. The result is that the coastal water in summer spreads seawards and pushes the eastern limit of the Atlantic current towards the west while the opposite movement takes place in winter. These lateral variations are combined with simultaneous changes in the depth of the coastal water. Analogous variations seem to exist with regard to the Gulf Stream off the coast of the U. S. A. and the Labrador Current and its continuation southwards. Apart from such local displacements which are caused by variations in the internal field of force, considerable displacements caused by seasonal variations in the wind conditions may occur. In this connection it may be mentioned that Professor NANSEN and I [1917, 1920] when investigating the annual variations of the surface temperature in the North Atlantic found that differences of temperature from one year to another were closely related to variations in atmospheric pressure and, consequently, in wind. This circumstance is chiefly due to the transport of the surface water by wind in places where the horizontal temperature gradient is fairly large. Similar seasonal changes and variations without any definite periodicity undoubtedly appear below the surface too.

Professor G. SCHOTT and others have made a statistical research into the annual range of surface temperatures of the ocean. In his "Geographie des Atlantischen Ozeans" SCHOTT [1926] has published a chart showing the geographical variations of the annual range of surface temperatures in the Atlantic. The chart is here reproduced in Fig. 9. It appears that there is an absolute minimum of the annual range in the tropics. A secondary minimum, with differences between summer and winter temperature less than 5° C, occurs in the ocean south east of Greenland. In the Azoric high pressure area there is a secondary maximum, the annual range exceeding 8° C. Within a broad belt, extending from Europe to America the temperature variation between summer and winter ranges from 5° to a little above 8° C. Off the east coast of the U. S .A. and in the vicinity of the Newfoundland Banks there is an absolute maximum of the annual range of temperature.

The conditions represented by the chart are easily explained. In the tropics the annual range is small, chiefly because of the position of the sun, with great noon altitude throughout the whole year and a relatively great cloudiness, the radiation being subject to small seasonal variations. In the Azoric high pressure area the seasonal changes in the altitude of the sun have a considerably more pronounced effect upon the absorption of heat, and because of the prevailing clear sky the radiation from the sea to the atmosphere in winter is fairly strong. Prevailing cloudy conditions and a deep-reaching vertical convection

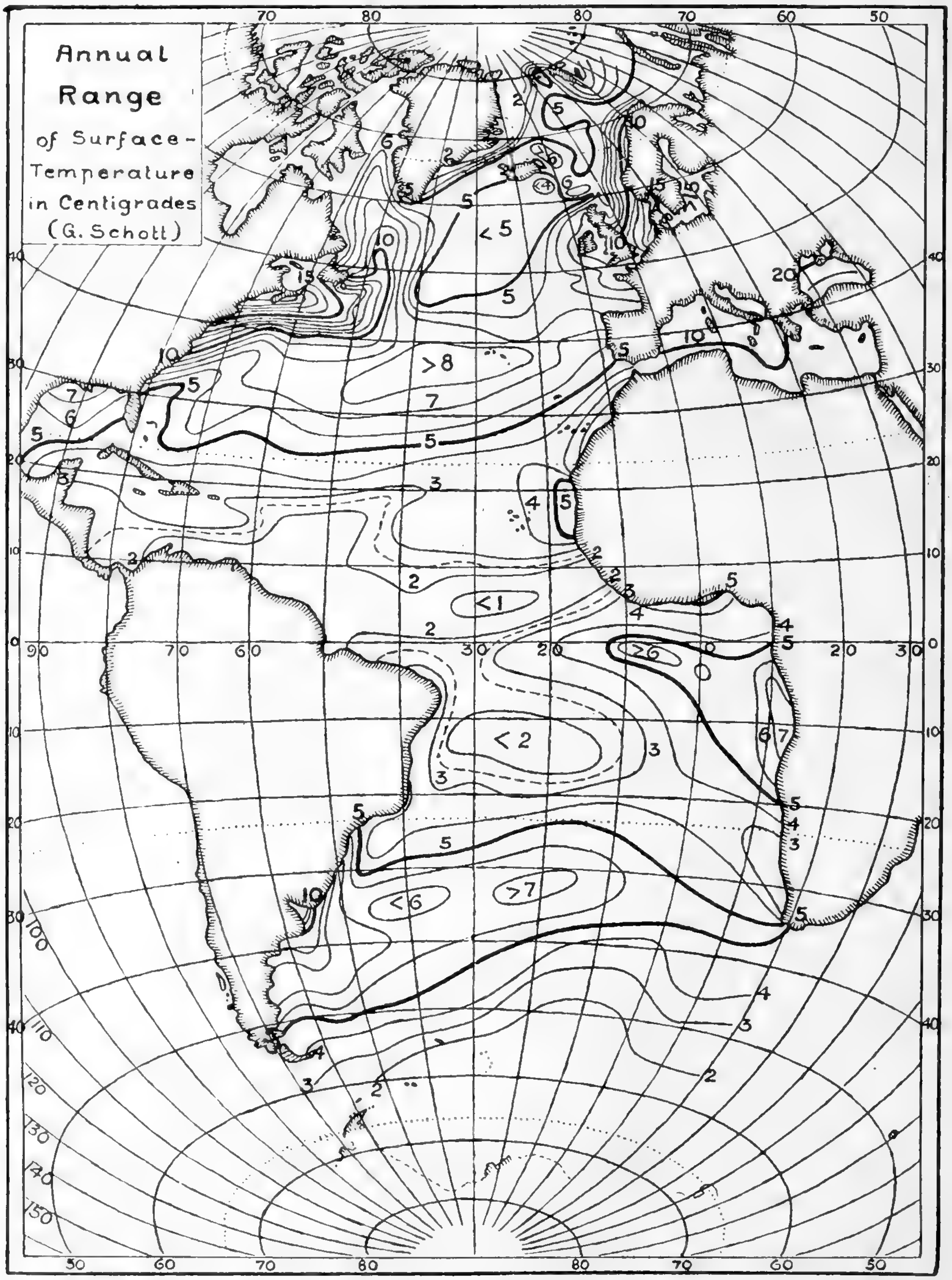


Fig. 9. The annual range of surface temperature in the Atlantic (according to G. Schott).

in winter cause a decrease of the annual range south-east of Greenland. The abnormally large range of temperature found off the east coast of the U. S. A. and Newfoundland, is primarily due to seasonal changes in the position of the currents. In this area there are abrupt transitions from warm to cold water and a seasonal variation in the relative distribution of these water masses, must necessarily cause particularly marked changes in temperatures referred to geographic co-ordinates.

For a study of the seasonal variations in the water below the surface the material of direct observations is very poor. In the literature I have found from deep off-shore parts of the eastern North Atlantic only 3 cases where serial observations have been taken at different seasons in the very same geographical position: One station W of Scotland, one SW of Ireland (referred to below), and one between Spain and Morocco. Each of these stations which have been taken by Danish expeditions, have been repeated once.

During the "Thor" expedition in 1905, serial observations were taken at 48° 4′ N. Lat. and 12° 40′ W. Long. on June 7th (Stat. 68) and again on September 2nd (Stat. 178). The conditions are demonstrated by the diagrams of temperature, salinity and depth ["T-S-(D)-diagrams"] in Fig. 10. The numbers written along the curves represent the depths of observation, in metres. There are some differences of salinity between the two series, but they are mostly small and within the limits of error at 25, 400 and 1500 metres. During these summer-months the temperature had increased 5·2° C at the surface, 5·38° C at 25 metres, 3·23° C at 50 metres, 0·40° C at 100 metres, and 0·11° C at 400 metres. By means of the curve on p. 74* we find the following "salinity-anomalies" in 1/100 ‰ and "temperature-anomalies" in 1/100° C (cf. section 18):

Depth Metres	Salinity-Anomaly			Temp.-Anomaly		
	178	68	Diff.	178	68	Diff.
0	— 100	— 24	— 76	702	210	492
25	— 86	— 12	— 74	642	113	529
50	— 40	— 5	— 35	337	42	295
100	2	1	1	— 20	— 13	— 7
400	4	4	0	— 44	— 45	1
800	10	16	— 6	— 104	— 167	63
1000	24	31	— 7	— 245	— 313	68
1200	23	29	— 6	— 259	— 308	49
1500	20	19	1	— 254	— 247	— 7

Owing to the differences in salinity, mentioned above, the differences in "temperature-anomaly" do not quite correspond to those in temperature. From the last column of the table we see that the variation of temperature at

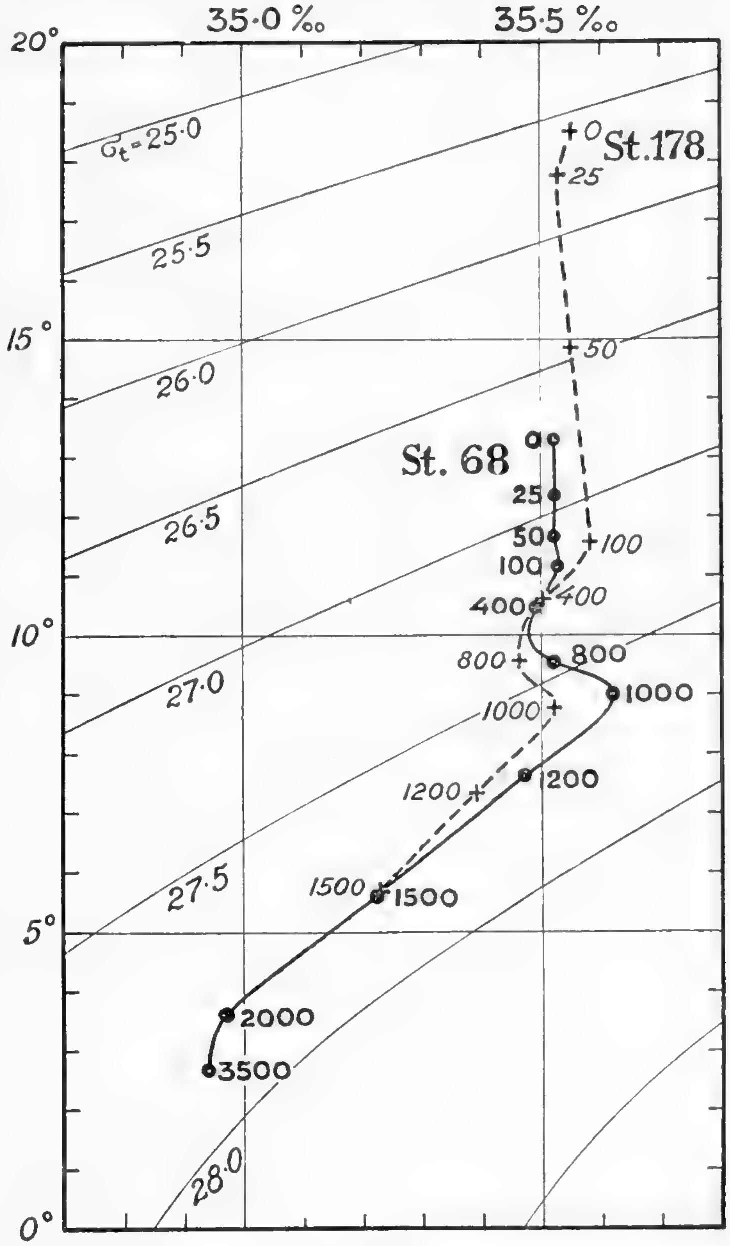


Fig. 10. Temperature-salinity-depth diagrams for the "Thor" stations 68 (June 7th, 1906) and 178 (September 2nd, 1906).

100 metres corresponds to a fall of temperature, when we take the variations of salinity into account. At 400 metres the variation is quite negligible. The high values of $\triangle \delta$ at depths between 800 and 1500 metres indicate a marked admixture of water from the Mediterranean at the locality in question. The differences from June to September between the anomalies at 800—1200 metres may suggest seasonal changes in the amount of Mediterranean water.

When we plot out on mm.-paper the temperatures observed at various dates, we obtain rather a motley picture of the seasonal variations, if the observations are limited to a certain area of the sea, including different

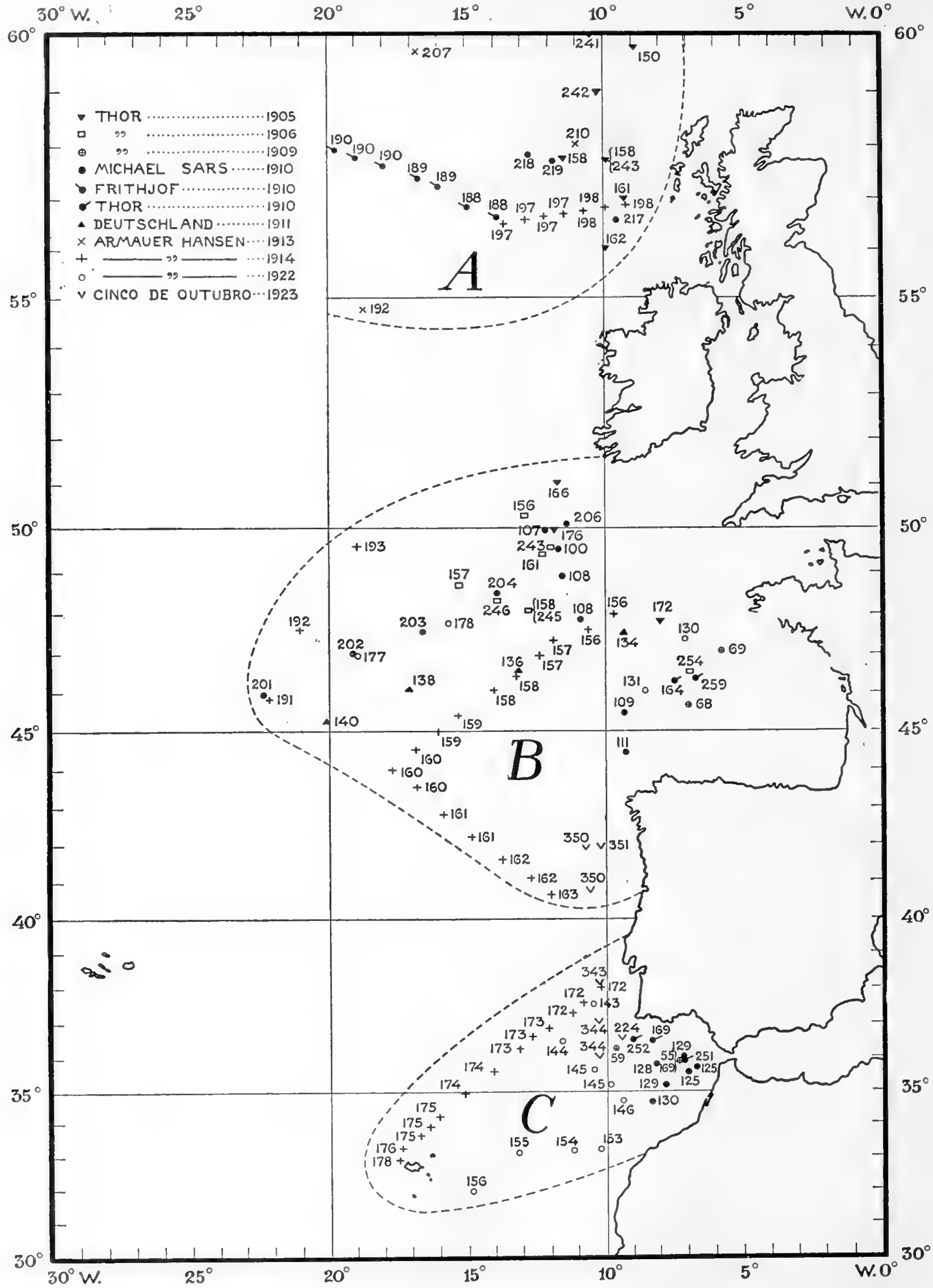
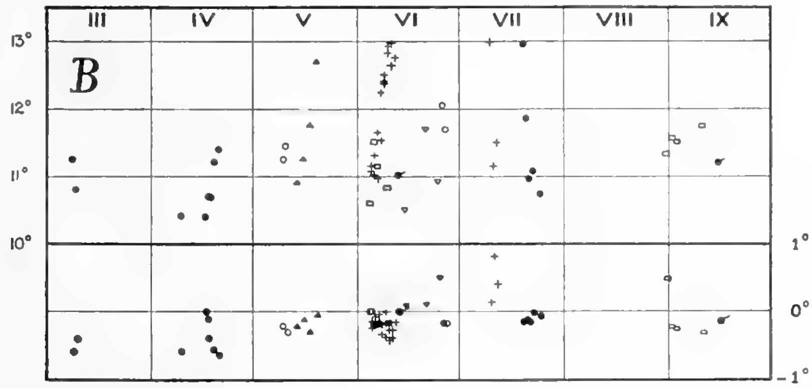
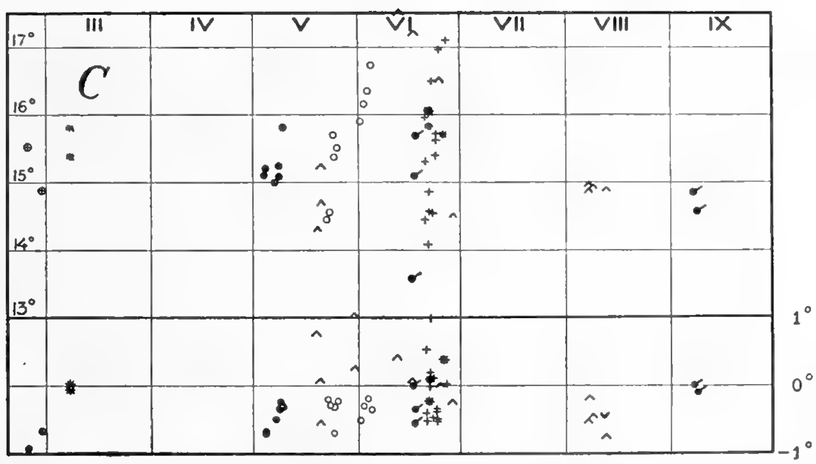


Fig. 11. Chart showing the stations with serial observations used by the analysis of the seasonal variations of temperature. The numbers represent the dates when the observations were made, counted from 1 (January 1st) to 365 (December 31st).

or variable currents. The observations will refer to water masses with different mean temperatures which are not directly comparable by a study of the seasonal changes. On the very same day quite different temperatures may be observed at the same depth at different stations. The spreading of the points on the mm.-paper is then too great to allow of a somewhat certain construction of a curve representing the seasonal variations. By means of Figs. 13 and 16 these stations from 1924 are marked ⁎ and from 1925 ∧. The material of observations comprises 13 different expeditions and 11 different years. The numbers which are inserted on the map give the dates of observation, January 1st having been reckoned as 1 and December 31st as 365.

To begin with stations from the whole of the eastern North Atlantic between 32° and 60° N were combined for





Figs. 12. (Area B) and 13 (Area C). Comparison between the direct observations of temperature at 100 metres (upper part of the figures) and the "temperature anomalies" calculated with deference to the salinities observed.

the above-mentioned "temperature anomalies" we may, however, to a considerable extent *reduce our original observations so that the variations of currents are partly eliminated.* By help of the curve on p. 74* the "normal" temperature corresponding to the salinity observed has been found and subtracted from the temperature observed. In the following we shall discuss the results obtained by this mode of proceeding.

The map Fig. 11 shows most of the stations which have been used. South and southwest of Portugal some stations taken with the "Albacora" in 1924 and 1925 could not be inserted in the chart for want of space. In the construction of curves representing the variations of temperature at different levels during a year. Some general differences appear, however, between the conditions in the northern, middle and southern regions. The observations were, therefore, divided in 3 groups as shown in Fig. 11:—A: NW of Ireland, B: the Bay of Biscay and the sea further west, and C: the area between Portugal, Morocco and Madeira. In the two northern areas only stations from places where the depth is over 1000 metres have been taken into consideration, and in the southern area only stations with a depth of 800 metres or more are included.

Figs. 12 and 13 demonstrate the difference in the results which one obtains by taking the actual temperatures and the "anomalies" of temperature. The graphs refer to 100 m. below the surface for the two areas B and C. The marks in the upper part of each of these figures show the variations in the temperatures directly observed while the marks in the lower part represent the anomalies mentioned. It appears quite clearly from these figures that the large dispersion which the direct observations of temperature exhibits is greatly reduced by the new method. The dispersion is, in fact, reduced mostly to one half or one third, in some cases even more. By help of the "temperature anomalies" one can, with a rather high degree of accuracy, draw mean curves whereby seasonal variations stand out clearly. Beside the seasonal variations some annual changes may occur, a point which we shall return to later on.

Most of the observations have been taken in spring and summer, and it is to be regretted that so few observations are available from September to April. The results with regard to the latter period are, therefore, rather uncertain. In the northern area A, there are no observations at all from the beginning of September to the end of May.

Figs. 14, 15 and 16 show the results from each of the 3 areas mentioned, for the surface, 25, 50, 100 and 200 metres. Even though, due to absence of adequate material of observations, many details may be uncertain the chief features of the seasonal variations in temperature seem to appear fairly clearly. The curves present the following results with regard to the upper 100 metres in the middle and the southern areas, the Roman ciphers indicating the months when minimum and maximum of temperature occur and $\triangle \tau$ the annual range of temperature:

Depth	Area B			Area C		
	Min.	Max.	$\triangle \tau$	Min.	Max.	$\triangle \tau$
0 m.	I	VIII	7·7	II	IX	5·3
25 „	II	VIII—IX	6·8	II	IX	4·7
50 „	III	IX—X	2·4	III	X	1·4
100 „	III	XII	0·7	III—IV	XI	0·9

The annual range found for the surface seems to correspond as nearly as may be expected to the values represented in SCHOTT's chart, Fig. 9. In the region corresponding to our area B the annual range of surface temperature varies from 6 to 8° C. according to SCHOTT. In the southern area the annual range found from the chart amounts to between 4 and 6° C. for most of the stations here dealt with. The coincidence is as good as may be expected and speaks in favour of the method here used.

The amplitudes are still large at 25 metres and not much less than at the surface. They decrease rapidly downwards. At 200 metres the amplitude as found from the curve is practically nought in the southern area. In the area off the Bay of Biscay the curve for 200 metres shows some greater variations, especially a narrow maximum in July, but these variations are rather doubtful (see further down).

In Fig. 17 the curves from the 3 areas from 0, 25, 50 and 100 metres are grouped together. The curves from one depth show great similarity in the general features, but some variations appear from one area to another which have a certain significance if they be real. These variations probably chiefly depend upon the different origin and the "history" of the water masses which dominate in the area.

The shapes of the curves do not correspond to simple curves of sine. At all depths the curves show a relatively flat course for the winter months. The physical explanation is evidently the following: When the surface water is cooled in late autumn and winter, the vertical convection makes the deeper water layers take part in the cooling. A neutral equilibrium or even a state of instability develops to greater and greater depths as the winter cooling goes on. In this way increasing quantities of water have to be cooled with the effect that the fall of temperature $\left(-\frac{\partial \tau}{\partial t}\right)$ becomes less and less. In the later part of the winter the water layers down to 100 metres or more give off some heat by being carried to the surface where the radiation outward and the convection of heat to the atmosphere exceed the absorption of solar radiation. Later on the heating of the surface starts and gives a relatively quick rise of temperature in the uppermost layers where the maximum of temperature is reached in August or September. The fall of temperature takes place comparatively rapidly at the surface and 25 metres in September, October and November. When the temperature at the surface rises, the stability just below the surface increases and reduces the virtual conductivity of temperature downwards. The deeper layers are thus comparatively little heated in summer (section 31) while the winter cooling in these layers is quite effective. This means that the mean annual temperature at, for instance, 50 and 100 metres is much lower than it would have been if the vertical conductivity of heat had been constant all the year round. The difference amounts to more than 2° C. The winter minimum at 50 and 100 metres shows much the same temperature as the minimum at the surface but the summer maximum at those depths is very low compared with the maximum at the surface.

The curves for 50 metres show a deformation in

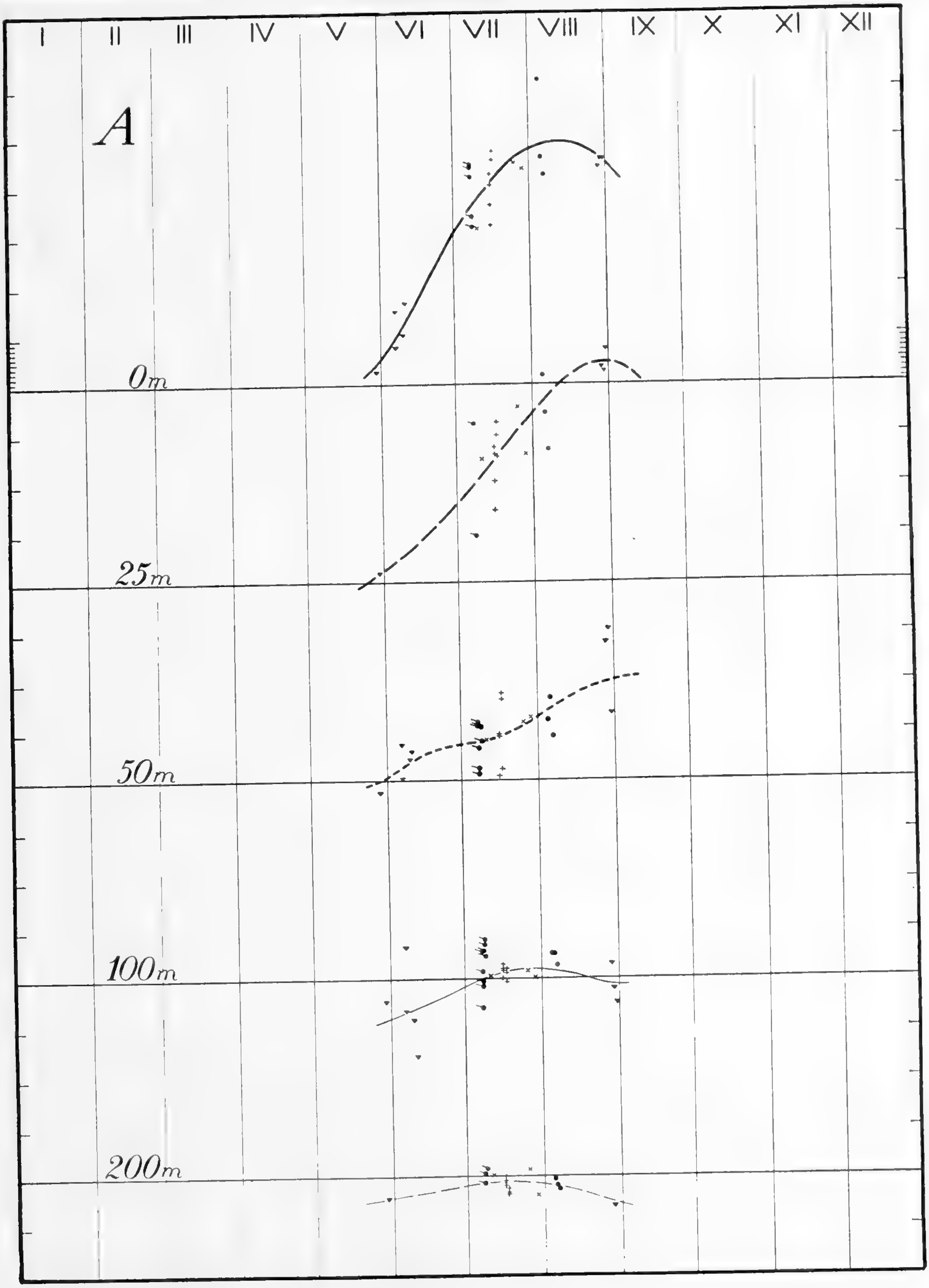


Fig. 14. Seasonal variations of temperature at different depths within the area N. and W. of Scotland and Ireland.

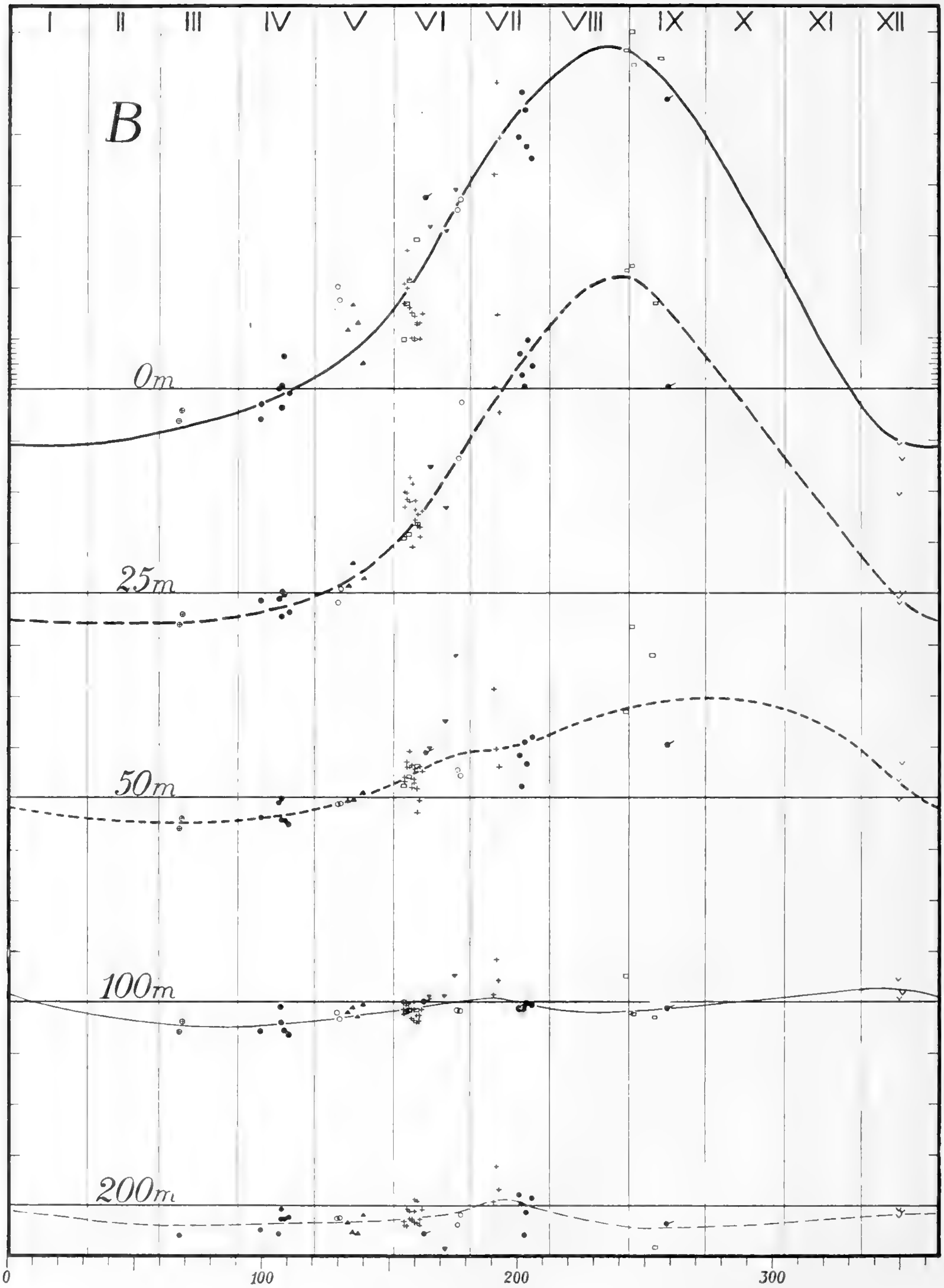


Fig. 15. Seasonal variations of temperature at different depths in the Bay of Biscay and westwards.

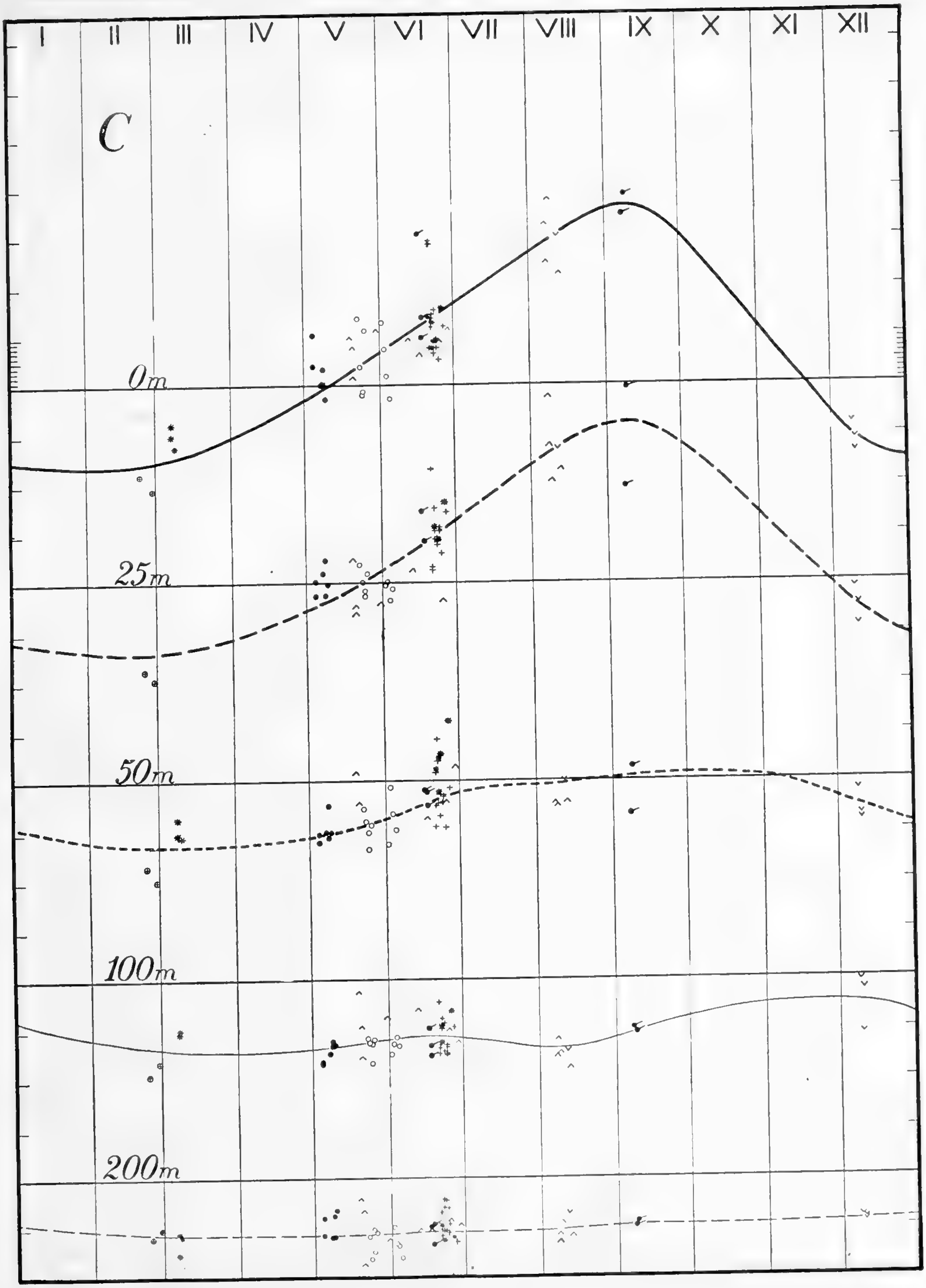


Fig. 16. Seasonal variations of temperature at different depths within the area between Portugal, Morocco and Madeira.

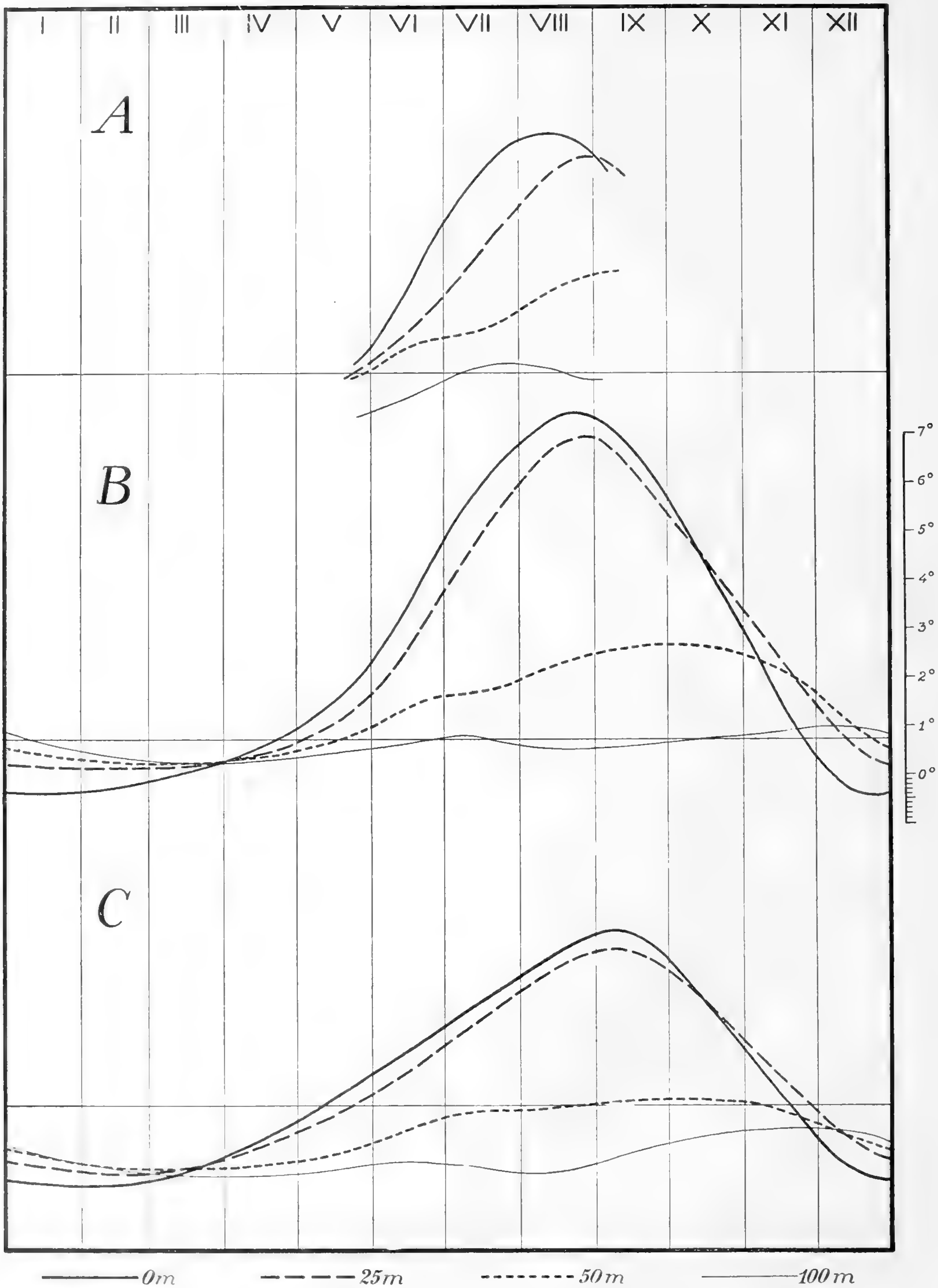


Fig. 17. The seasonal variations of temperature at 0, 25, 50 and 100 metres within the three areas A, B and C in the eastern North Atlantic.

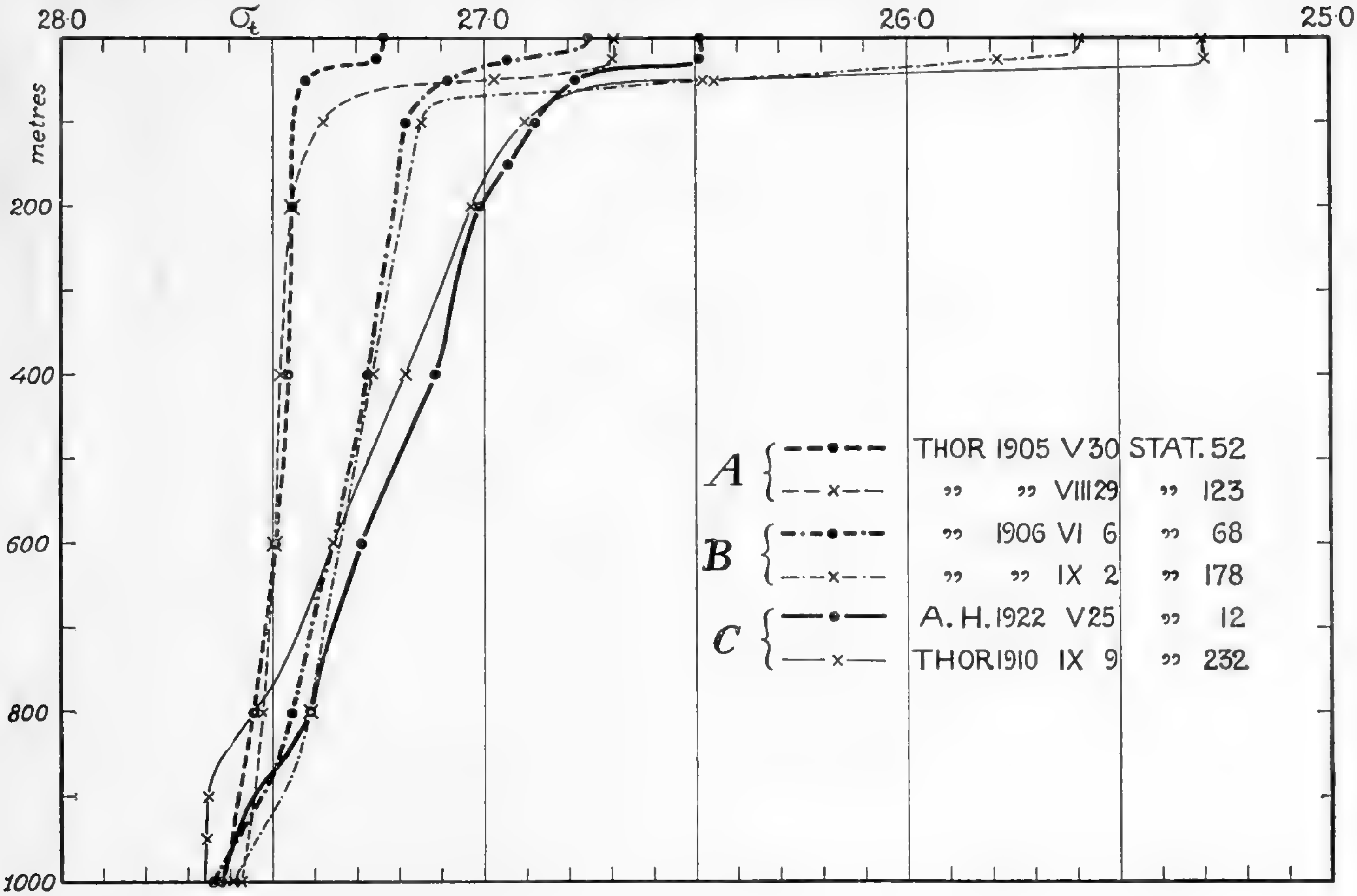


Fig. 18. The vertical distribution of density at 3 pairs of stations in the eastern part of the North Atlantic.

summer. In May and June the temperature increases fairly rapidly at this depth but afterwards the rise of temperature seems to be comparatively slow during some weeks, and then it becomes quicker again. This course of the variations may be explained by the variations in the virtual conductivity of temperature. Fig. 18 illustrates the variations of density from the end of May or beginning of June to the end of August or beginning of September at three pairs of stations, one pair from each of the areas in question. Both stations from area B are taken at the same place; they are the same stations as represented in Fig. 10. The stations belonging to each of the other pairs have not exactly the same position but are situated near each other. The curves demonstrate that the discontinuity layer develops very much from the end of May to the end of August in intensity and thickness. To begin with the discontinuity layer chiefly appears at about 25 metres or a little deeper. In July it has evidently developed so much that the conductivity of heat further downwards is very much reduced with the result that the rise of temperature at 50 metres is effectively retarded.

All the time an absorption of heat radiation takes place at 50 metres. As shown in section 30 this absorption gives a heating corresponding to an average rise of temperature of about 0·004° C per day or 0·12° C per month in the summer half. The "temperature anomalies" show in area B an increase of temperature in July and August of 0·82° C or nearly 0·6° C more than accounted for by the absorption of heat. According to the curve in Fig. 16 the increase of temperature in July and August is 0·25° C in the southernmost area (C) which corresponds exactly to the heating calculated for the absorption. In this case, no variations at 50 metres should take place on account of conduction of heat during this time of the year. It is quite obvious that the conditions so far are different in different areas, as the currents and the degree of stability are subjected to regional variations.

At 100 metres a deformation of the curves similar to that at 50 metres appears in summer. It is still more marked in relation to the total seasonal variations than at 50 metres. If the curves are rightly drawn they demonstrate even a secondary minimum of temperature in August.

Such a minimum would mean that the conduction of heat from above has stopped for some time and colder water below affected the temperature. An examination of temperatures seem to show that $\frac{\partial^2 \tau}{\partial z^2} > 0$. By $\frac{\partial \tau}{\partial z} < 0$

and $\frac{\partial \tau}{\partial t} < 0$, $\frac{\partial \nu}{\partial z}$ must, then, be > 0

and $\left|\frac{\partial^2 \tau}{\partial z^2}\right| < \left|\frac{\partial \nu}{\partial z}\frac{\partial \tau}{\partial z}\right|$. (Cf. section 31, case III, Fig. 6). The observations have not been made at so small vertical intervals that a more detailed examination can be performed.

The "anomalies" of temperature at 200 metres seem to show a narrow, but fairly prominent maximum of temperature in July in area B. It corresponds to the smaller maximum at 100 metres in the same area. The course of the curve is, however, rather doubtful. Changes from one year to another and not seasonal variations may have asserted themselves. Apart from this special feature the curves for 200 metres show an annual range of 0.3° C in area B and 0.25° C in area C.

Our examination leads to the result that the seasonal variations in temperature are quite small at depths below 200 metres, when we disregard possible changes in the velocity and direction of the currents.

Even at 100 metres the temperature variations are so small that they in most cases are of subordinate importance in comparison with the local variations of temperature. For smaller depths observations from different seasons cannot generally be combined without a reduction to a certain time of the year. As the variations in temperature go nearly parallel to variations in density, the seasonal changes must be taken into account by exact calculations of the total pressure at certain depths or the depths from the sea surface to certain isobaric surfaces.

When the amplitude and phase of the seasonal variations of temperature at different levels are known, the virtual coefficient of temperature conductivity may be calculated. The mathematical operations are, however, complicated because the coefficient of conductivity itself is subjected to seasonal varitions. On my request, Dr. J. E. FJELDSTAD of the Geophysical Institute at Bergen has performed a mathematical investigation of the problems. A solution is found on the assumption that the coefficient of temperature conductivity during the year varies with time as a function of sine. The effect of the absorption of heat radiation has been taken into account. A full report on these investigations will be published in another place later on, and here only the following results with regard to area B may be stated:

In the uppermost water layers the virtual coefficient of temperature conductivity has an average value of about 20 C. G. S. units. The value decreases fairly rapidly to a value which is nearly constant, at any rate down to 100 metres, and amounts to about 3 C. G. S. units as an average for the whole year. The seasonal changes make the latter value vary between about 0·5 (in summer) and 5·5 (in winter).

These numerical values of the coefficient of temperature conductivity are much smaller than those of the coefficient of virtual friction. Many authors have tried to calculate the latter. It has been found that the coefficient of friction is very small in discontinuity layers, but otherwise it may attain very high values. Values of about 200 C. G. S. units seem to be comparatively common in the sea [cf. V. W. EKMAN, 1927]. The ratio between the virtual coefficient of temperature conductivity and the coefficient of friction is probably of the order of magnitude 10^{-1} and may perhaps sometimes be 10^{-2}. The difference between the two coefficients is understood when we assume that the water particles rapidly alter their momentum according to that of the surrounding particles, while the variation of heat (and contents of salt etc.) inside the particles takes place comparatively slowly, and is not established before many of the particles in turbulent motion return from their new position.

The differential equations and their solution result in curves of the very same shape as those represented in our figures, and verify the physical discussion given above. The curves based upon the mathematical investigations show a long-stretched minimum, a comparatively narrow (pointed) maximum near the surface, and a relatively slow rise from minimum to maximum and rapid fall from maximum to minimum at 50 and 100 metres. They show even a variation in the rate of the temperature rise in summer at the latter depths, of a similar kind as described above, though not so marked.

The seasonal variations dealt with above are those which are, so to speak, of a purely thermal character and which commonly start from the surface and propagate downwards. We have tried to eliminate the effect of changing currents as regards their higher or lower (absolute) mean temperatures, in order to obtain sufficient data for constructing the temperature curves in question. By our mode of proceeding, the seasonal variations of temperature in a current which is relatively warm may be juxtaposed with those in water masses which are colder all the year round. But even the observations from the eastern North Atlantic — where the number of stations hitherto worked is relatively large — do not afford sufficient material for a more detailed analysis. Up to the present, we cannot treat properly either the variations in the distribution of

the single currents ("dynamical variations", in relation to geographical co-ordinates) or the individual seasonal variations of temperature within them ("physical variations", in relation to "oceanographical co-ordinates", cf. above p. 47). The difficulties arise from the local variations which are so often met with.

In the deeper strata below 200 metres, where the surface exerts next to no influence apart from the winter convection in some areas, seasonal variations in temperature may occur as a result solely of variations in the course and velocity of the currents.

The current system of the eastern North Atlantic seems to be rather complicated. In our discussion of all modern observations made in this part of the sea up to the year 1922 Professor NANSEN and I came to the conclusion [1926] that a number of vortices arise and reveal their presence by great variations of temperature and salinity within short distances (local variations). This holds good on the assumption that the observations may be directly combined in sections and charts, and that the variations are not caused to any great extent by vertical oscillations. At about 1000 metres below the surface, water from the Mediterranean makes itself felt in a variable degree. The salinities and temperatures are, relatively, very high at this depth in the Atlantic near the Straits of Gibraltar. Here we find very high positive values of salinity-anomaly (or negative values of "anomaly of temperature"). These anomalies gradually decrease in all directions as one moves away from the outlet from the Mediterranean. The local variations are so great that it is not worth while to try to use the same method for these intermediate depths that we have adopted in the above discussion of the upper water-layers.

At 400 metres the conditions are much more uniform than at about 1000 metres. Fig. 19 shows the temperatures observed at 400 metres within our area "B" (the upper part of the Fig.) and the corresponding "anomalies of temperature". The different marks have the same significance as in Figs. 11, 12 and 15. The dispersion of the marks is rather great, on account of the local variations. There is no definite indication of any seasonal variations at this depth. It may also be referred to Figs. 21—23.

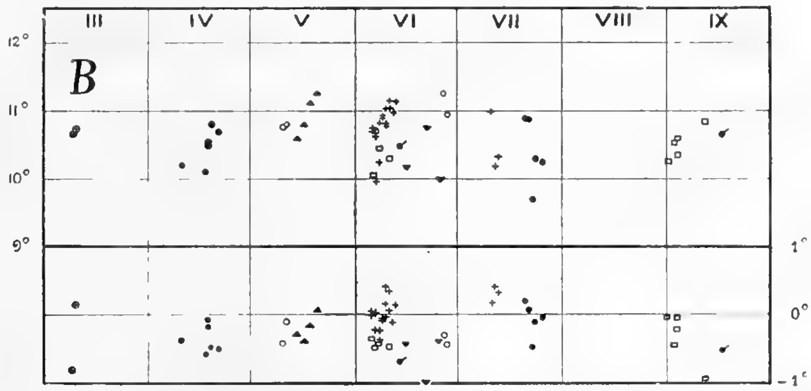


Fig. 19. Temperatures observed (upper part of the figure) and the corresponding "anomalies of temperature" at 400 metres in area "B".

33. Variations from One Year to Another (Annual Variations).

In the preceding section we have discussed the variations of temperature which, on an average, take place in the course of one year within different areas. Within one and the same area considerable changes may, however, occur from one year to another, in the manner which is so familiar in meteorology. A certain month or season may be warmer or colder in one year than in another, and in most cases we find positive or negative departures from the mean temperature of the epoch. For the sake of brevity we shall term these variations *annual* variations in contradistinction to the average changes from season to season.

When discussing oceanographic observations which had been made in the Norwegian Sea during a number of years, Professor NANSEN and the present author found [1909] that the temperature of the Atlantic water ($S > 35$ ‰) in this sea in May was subject to considerable annual variations. The Atlantic water entering the Faeroe-Shetland Channel becomes mixed with Arctic water, and the annual variations exhibited farther to the north may be explained either by the different proportions in which the water-masses are mixed or by variations in the temperature of the single constituents. In order to decide this question we have tried to examine the annual variations in the North Atlantic, but for want of more adequate material we had to confine ourselves merely to a study of the surface temperatures towards the end of the winter

when they may also be expected to represent the water at considerable depths below the surface, in consequence of the vertical convection in the cold season. Our examination embraced observations taken between February 3rd and March 4th and partly also between March 15th and April 15th in each of the years 1898—1910 [HELLAND-HANSEN and NANSEN, 1917, 1920].

Fig. 20 illustrates some of the results of this investigation. The curves show the variations of surface tempera-

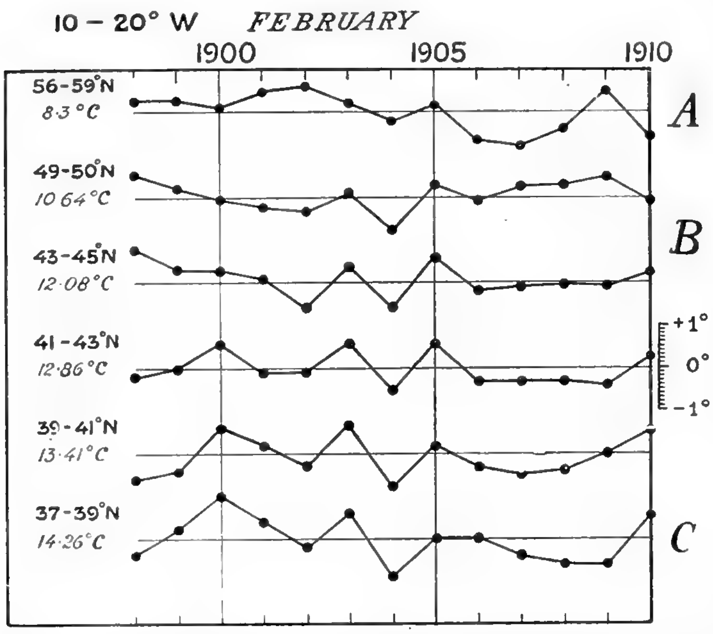


Fig. 20. Variations in the surface temperature for February in the eastern North Atlantic between 10° and 20° W. and between 37° and 59° N.

ture for the first of the two epochs mentioned (February) in the North Atlantic off Europe between 10° and 20° W. The temperatures at the base-lines are the mean temperatures for February referred to the 11-year period 1900—1910. The uppermost curve belongs to the area called "A" in section 32 (see Fig. 11); it represents the conditions within a belt which goes NE—SW and is about 2 degrees of latitude in width. The other curves represent the conditions in an E—W direction, the second curve from above referring to a field which is 1 degree of latitude in width, the others to belts of 2 degrees. Curves 2 and 3 fall well within the area "B", and the lowermost curve within "C".

The difference between the highest and lowest temperature for February recorded during the years 1898—1910 amounts to about 1·5° C (taken in the same succession as the curves in Fig. 20, beginning from above, the figures for the separate fields are: 1·4, 1·3, 1·4, 1·1, 1·5 and 1·9° C). There is sometimes a difference of 1° C or more between February in one year and February in the following year. We observe that taken as a whole the curves change from one field to another, which means that *the annual variations in the temperature of the upper water-layers are not the same within different areas even if these are fairly small and not far apart.* The transitions are, however, mostly gradual, representing a certain progression in the appearance of the anomalies. Some features are common to all the curves, as, for instance, a fall in the February temperature from 1903 to 1904, a rise to 1905 and then a fall again to 1906, but the magnitude of the variations is not the same everywhere.

As a rule the perfect mixing of the upper water-layers due to the vertical convection in winter has not reached its maximum depth as early as February; — generally it is not completed until the middle of March or later. The surface temperature in February may, however, be regarded as being approximately representative of, say, the upper 100 metres, especially when the temperature is below the mean average for the month. The seasonal variations at 100 metres below the surface are relatively small according to the results set forth in the preceding section, and from February to June or even August—September they are smaller than many of the annual variations exhibited by the curves in Fig. 20.

We have only a very scanty number of observations for the direct study of possible annual variations at 100 metres or any other depth below the surface. As mentioned above, a departure of a "temperature-anomaly" (in the sense described in section 32) from the average of the date, may to some extent indicate annual variations. It must, however, be borne in mind that our examination of the seasonal variations of temperature in the upper water-strata is based upon very heterogeneous material, the observations having been collected from water-masses (currents) of different origin with unequal salinities. We have tried to eliminate the local changes and find the average seasonal temperature-variations, of what may be called a purely thermal character, for fairly large areas. Our method of elimination is not, and cannot be, so perfect that the irregular distribution of the points in graphs representing the actual temperatures altogether disappears; although it is much reduced. We have just drawn attention to the fact that the annual variations in the upper water-strata do not, as a rule, run parallel over very wide areas of the ocean, but alter from one field to another. Some of the water-masses may, therefore, have arrived on the scene with an original temperature which deviates, to a larger or smaller extent, from the temperature of the other water-masses in the same area as regards the annual variations. Thus we cannot expect to find exactly similar anomalies everywhere within even a limited field where the annual variations may show appreciable differ-

ences from one locality to another. Even if we could restrict our examination to a characteristic current, the results might be rather doubtful, because the velocities may differ greatly in horizontal and vertical direction. Besides the purely thermal ("physical") variations we may have changes in the distribution and intensity of the currents ("dynamic" variations), of such a nature that the actual mean temperature within an area may be higher or lower than the normal, even if the "anomalies of temperature", found by means of the salinities, do not indicate it. In consequense of all these complications, the unravelling of the annual variations of temperature in the sea is at present very difficult. The material we possess may, however, give some indications.

In the North Atlantic E. of 20° W. the velocity of the currents may be very considerable at about 100 metres below the surface, but probably in limited regions only. In our area "B" (Fig. 11) the velocity on the whole seems to be relatively small at such moderate depths, so the water is not carried far in the course of several weeks or months. A rapid motion in vortices is of no consequence in this connection. Accordingly we may compare the "anomalies of temperature" for moderate depths in spring with the temperature of the surface in February. A similar comparison may to some extent be carried out for "C". From area "A" the material is too small.

A comparison of Fig. 20 with Figs. 15 and 16 may give us some hints, but only in respect of the years 1905, 1906, 1909 and 1910. We have no data from other years for this purpose.

From *1905* we have 3 stations within area "B" in June, at about 51°, 50° and 48° N. (the latter station at about 8° W.) We have observations from 4 other expeditions and years in this area in June so that the average variation of temperature during this month is fairly well established (Fig. 15). The stations from 1905 seem to indicate that the temperatures at 50 and 100 metres below the surface were above the average for the times of observation. This agrees with the annual variations exhibited by the curves in Fig. 20 (the second and third from the top).

In *1906* we have some stations taken by the "Thor" expedition in the northern part of our area "B" during June and August-September. The observations from June show normal temperatures at 50 and 100 metres, in accordance with the corresponding curve (the second from the top) in Fig. 20.

In *1909* two stations taken from the "Thor" in the sea S. of Portugal (area "C") at the end of February show relatively low temperatures at all depths between the surface and 100 metres, which corresponds well with the low temperature at the surface in the nearest field to the NW (the lowest curve in Fig. 20). Two stations in the Bay of Biscay ("B") at 45° 37′ and 47° 1′ N. in March (Fig. 15) seem to accord well with the normal conditions exhibited by curve no. 3 in Fig. 20.

The "Michael Sars" observations from *1910* in area "B" in April and July seem to correspond to normal temperatures, as do also the surface observations in February. Some "Michael Sars" and "Thor" stations in the sea between Portugal, Spain and Morocco (area "C") indicate normal temperatures in May and June 1910 at 50 and 100 metres, while the surface temperature in the sea W. of Portugal was relatively high in February. (I have no material at hand to find the mean surface temperature and its relation to the normal temperature in this region in March).

On the whole, there seem to be fairly good indications of a *direct agreement between the annual variations of the surface temperature towards the end of the winter and the temperature for a considerable time (several months) afterwards at 50 and 100 metres,* the transport of the water from one field to another being taken into consideration.

Assuming that our graphs in Figs. 15 and 16 may be utilized for tracing further indications of annual variations in the upper water-strata, we find that spring and early summer may be characterized as normal in *1911* in area "B"; we have no observations of this kind from "C" in that year. The temperature was nearly normal in *1914* in both the areas "B" and "C", and in *1922* in "B". In the latter year the temperature was probably slightly below the normal in area "C", where it seems to have been relatively high in *1924* (March and May). The conditions in 1925 are uncertain.

Fig. 21 illustrates the vertical distribution of temperature, salinity and density at the "Michael Sars" station 89 in 1910 and the "Armauer Hansen" station 58 in 1914. The stations had nearly the same position. The dates correspond to the numbers 201 and 191 in the chart, Fig. 11. In the same way the two next figures illustrate the conditions at a "Michael Sars" station and another taken quite near it but in a different year. The years (and dates) of the observations represented in Fig. 22 are 1910 (202) and 1922 (177); and in Fig. 23 they are 1910 (204) and 1906 (246). The differences in temperature and salinity between one of the alien stations and the corresponding "Michael Sars" station have been computed for various depths, and are illustrated in the diagrams inserted to the right in the figures.

Leaving the uppermost water-strata out of account we see from Figs. 21—23 that the temperature at the stations considered was, on the whole, lower in 1910 than in the other years. At the same time we find differ-

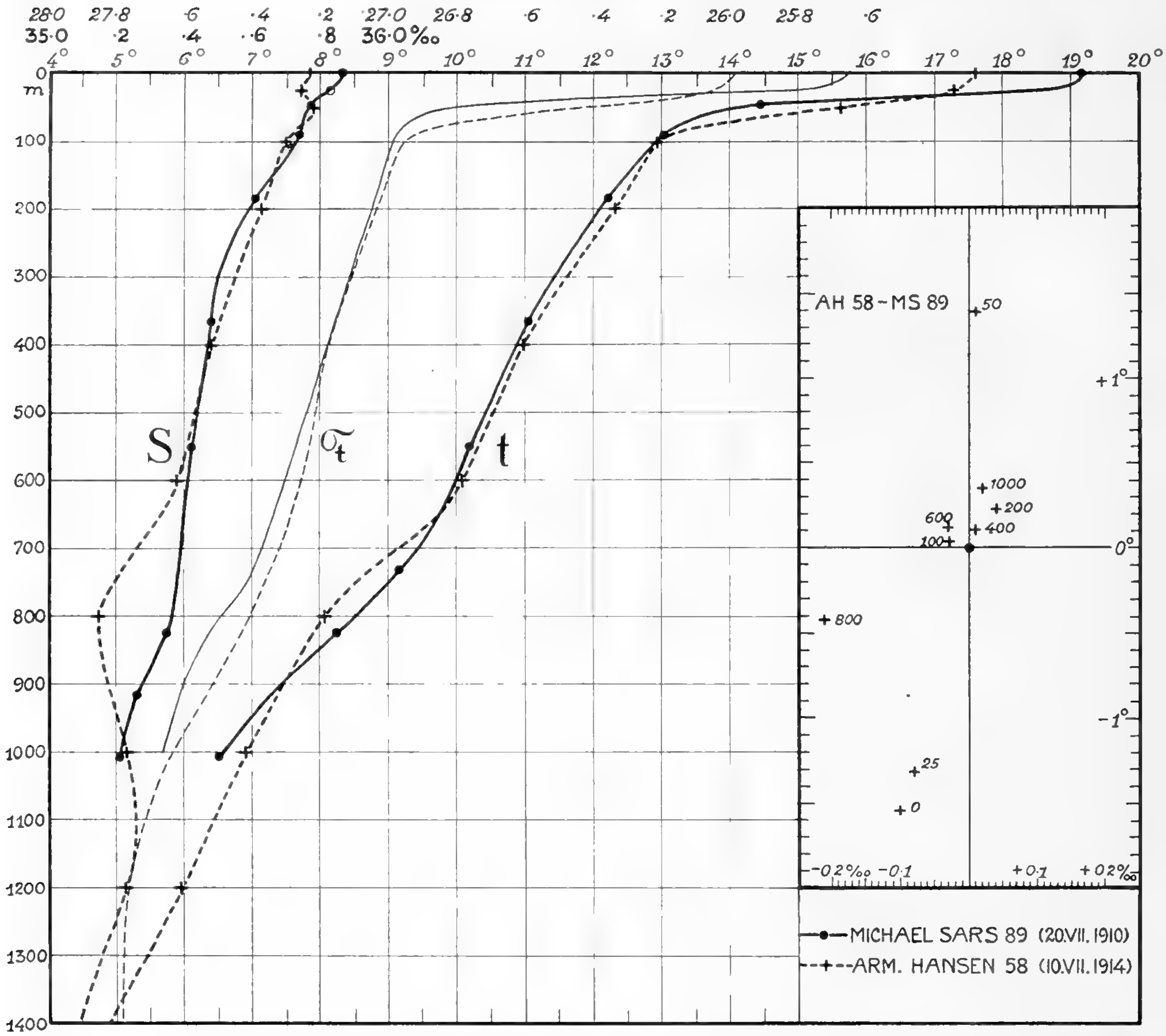


Fig. 21. Comparison between the "Michael Sars" station 89 (in 1910) at 45° 55′ N., 22° 24′ W. and the "Armauer Hansen" station 58 (in 1914) at 45° 45′ N., 22° 15′ W.

ences of salinity which for the most part accord well with the general rule of correspondence between temperature and salinity. The differences of temperature are obviously not attributable to such seasonal changes as start from the surface and propagate downwards. The largest differences at depths *between 200 and 600 metres* are, in fact, exhibited by the curves in Fig. 22, representing a case where the higher temperatures were observed towards the end of June (1922) and the lower towards the end of July (1910). Owing to variations in salinity parallel to those in temperature, the densities were practically identical at both stations. In the two other cases the differences of temperature (and of density as well) were only small at the depths named.

Below 600 metres the variations are considerable larger than at the higher levels. We will only give a few characteristic examples. At the "Michael Sars" station 89 on July 20th, 1910, the temperature at 800 metres was nearly half a degree centigrade higher than at the "Armauer Hansen" station 58 on July 10th, 1914 (Fig. 21). The difference of salinity was, relatively, larger still, so the density was higher at the warmer "Michael Sars" station than at the other. At 1000 metres the temperature was higher at the "Armauer Hansen" station than at the "Michael Sars" station. By finding the anomalies of salinity based upon the temperatures observed, we obtain the following values:

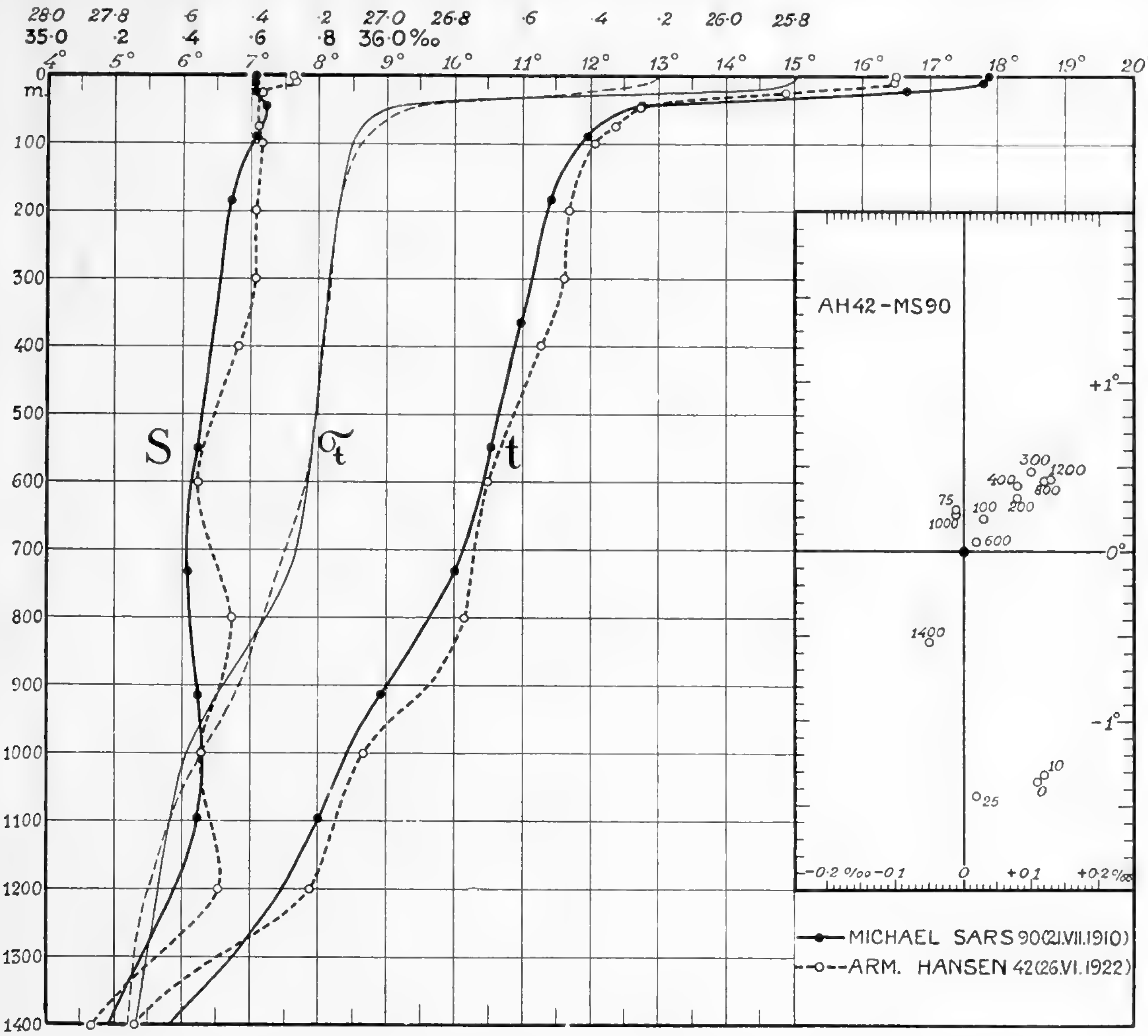


Fig. 22. Comparison between the "Michael Sars" station 90 (in 1910) at 46° 58′ N., 19° 6′ W. and the "Armauer Hansen" station 42 (in 1922) at 46° 56′ N., 18° 54′ W.

	"Michael Sars" Stat. 89	"Armauer Hansen" Stat. 58
800 metres	10	— 7
1000 —	11	10

When we consider that △S, at the depths in question in the eastern part of the North Atlantic, gets relatively high positive values where there is an admixture of water from the Mediterranean, while water from the northwestern part has negative values (cf. the charts p. 97*) we may venture to infer that practically no water from the Mediterranean was present at the "Armauer Hansen" station at 800 metres, though such water exerted quite an apreciable influence at this depth at the "Michael Sars" station some few miles to the north-west. This can hardly be explained by local variations; it must probably be attributed to annual variations. At 1000 metres hardly any difference exists between the two stations as regards the effect of water from the Mediterranean, though some difference appears in the absolute values of temperature and salinity.

Turning to Fig. 22, we have to make proper allowance for the uncertainty in the construction of the curves, which is due to the fact that the depths of observation (below 600 metres) are relatively few and more unequal at the two stations than in the cases illustrated by Figs. 21 and 23. We find, nevertheless, that there are prob-

ably considerable differences between the two stations represented in Fig. 22. $\triangle S$ has the following values:

	"Michael Sars" Stat. 90	"Armauer Hansen" Stat. 42
800 metres	6	13
1000 —	21	23
1200 —	20	30
1400 —	14	12

These values seem to indicate that water from the Mediterranean made up a less prominent part of the water-masses between 800 and 1200 metres at the "Michael Sars" station than at the other.

For the stations represented in Fig. 23 we obtain the following values of $\triangle S$:

	"Michael Sars" Stat. 90	"Thor" Stat. 180
800 metres	6	11
1000 —	21	25
1200 —	20	23

Here again, we have lower values at the station from 1910 than at the other station. The differences are however, not so conspicuous as the differences in the absolute values of temperature and salinity.

It is quite obvious that the physical conditions at about 800—1200 metres in the region W. of the Bay of Biscay are subject to great changes, either local or temporal. The charts on pp. 96* and 97* and the more detailed charts in Figs 28—29 are based upon all observations available regardless of possible annual or other temporal variations (cf. section 36). No doubt, the local variations at about 1000 metres may be very large in many parts of the eastern North Atlantic. To a great extent they are connected with the presence of water from the Mediterranean and would be found by perfectly synoptic observations too, even if some details in the charts would then be altered. An advance or a retreat of the water-masses in a horizontal direction, as well as changes in their vertical position, may produce a great effect at particular places (stations), and evidently such changes may come under the category of annual variations. Besides such fluctuations we probably also have variations in the temperature of huge bodies of water in general, and, as far as the eastern North Atlantic is concerned, in the proportionate amount of water from the Mediterranean that is present in the mixed water-masses at intermediate depths. The consideration of these phenomena suggests some interesting and important problems, but it would lead us too far afield to enter into them here.

We have chiefly discussed the conditions in the eastern part of the North Atlantic, from which we have a comparatively large number of observations. Even here, however, a study of the annual variations must necessarily be unsatisfactory; and this is still more true when we turn to other parts of the North Atlantic, from which we have no material at all for such studies. In the preliminary report on the "Michael Sars" Expedition the present author [1912] made a comparison between serial temperatures taken by the "Challenger" and the "Michael Sars", which seemed to indicate that the temperatures down to about 1000 fathoms were lower, and sometimes very much lower, in 1910 than in 1873 in the regions around 37° N. and 48° W. This conclusion, however, is very doubtful, as insufficient allowance was made for possible local variations.

34. Adiabatic Variations of Temperature.

When a good insulating Pettersson-Nansen water-bottle, which is fitted with a Nansen thermometer (cf. section 11) and a reversing thermometer as well, has been closed at a fairly great depth and hauled up quickly it will be found that the two thermometers indicate different temperatures. The Nansen thermometer will show a lower temperature than the reversing thermometer. An observation, for example, from 4000 metres in the North Atlantic will give a difference of about 0·45° C if the insulation of the water-bottle is perfect. This is a result of the diminution of pressure from about 400 atmospheres to 1 atm., and is explained as follows: when a compressible fluid has been exposed to pressure, and this pressure is diminished, the fluid expands. The expansion represents a quantity of work which is performed at the cost of the heat energy in the fluid if no corresponding quantity of heat is added from other, *i. e.* exterior, sources. The temperature must consequently decrease when no interchange with the surroundings takes place. If, on the other hand, a compressible fluid is exposed to increased pressure, some energy is added to the fluid and manifests itself by heating it. Such *adiabatic* variations of temperature are well known in meteorology. Nansen [1901, 1902] has introduced the problem of adiabatic processes into oceanographic discussions.

In our example with the insulating water-bottle not only the water-sample but also the solid parts of the water-bottle are subject to adiabatic expansion. If it were not for these solid parts, the decrease of temperature within the water-sample would be less than that stated above, and amount to about 0·35° C. with a sample lifted from 4000 metres to the surface in the North Atlantic. This change represents the adiabatic variation of

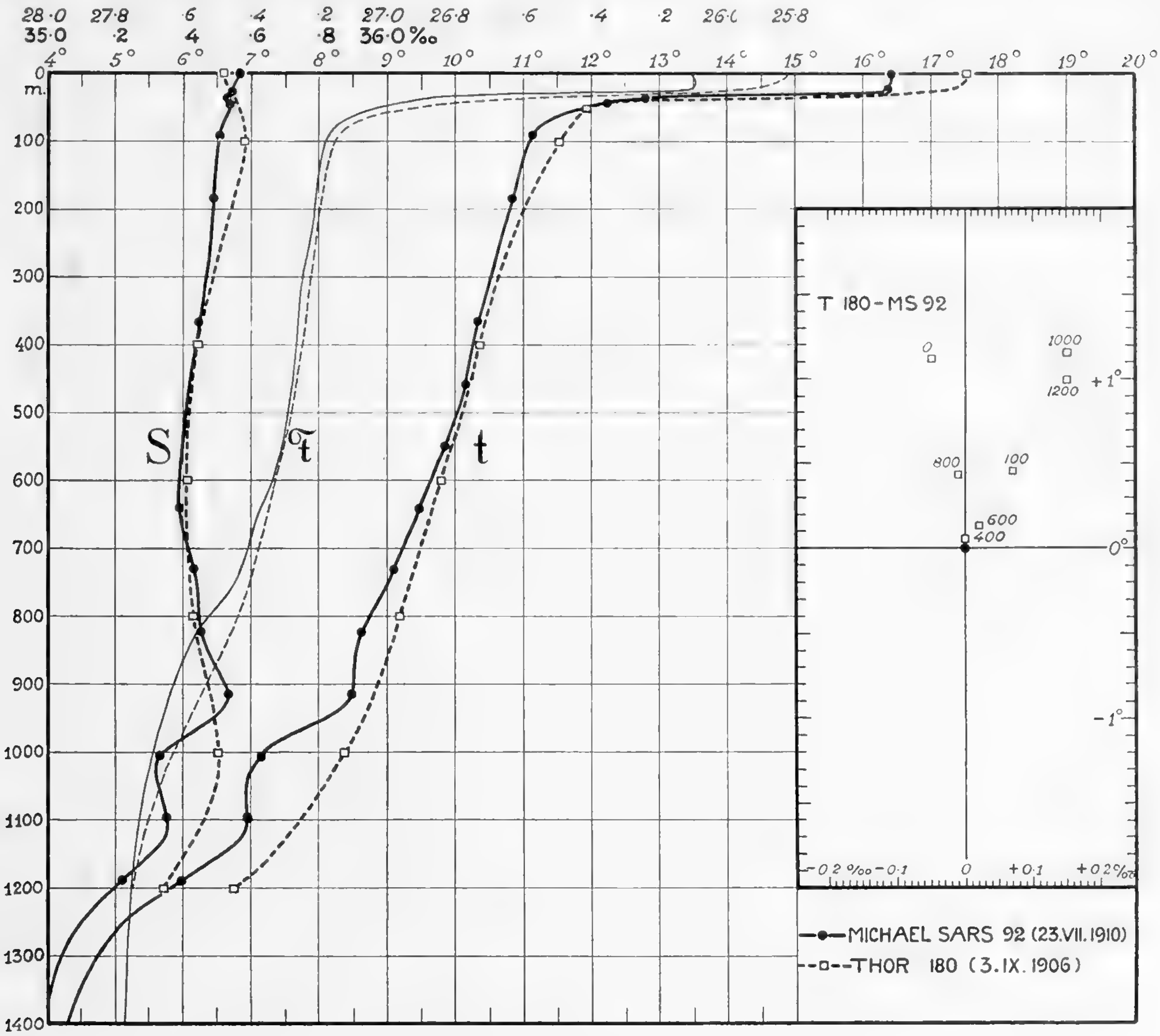


Fig. 23. Comparison between the "Michael Sars" station 92 (in 1920) at 48° 29′ N., 13° 55′ W. and the "Thor" station 180 (in 1906) at 48° 19′ N., 13° 53′ W.

the temperature of the water in the absence of any foreign bodies.

Let us assume that the water from the surface to a great depth is so perfectly mixed that a neutral equilibrium is established. The salinity must then be the same at all levels, while the temperature will show an increase downwards corresponding to adiabatic changes. The "bottom-water" in the great depths of the oceans is homohaline, and is relatively cold. It must have been at or near the surface in some region where it obtained a low temperature before sinking to the abysses of the sea. While sinking it is heated adiabatically. If the deep water consists of water-masses which originally — when leaving the upper levels — were perfectly uniform with regard both to salinity and temperature, and the uniformity has not been disturbed by other processes than variations in pressure, or if the descending water-masses are thoroughly mixed at greater depths, we may expect to find an adiabatic distribution of temperature. A slow heating takes place from the bottom of the sea and contributes to create such a distribution; in certain circumstances we may even expect an "over-adiabatic" fall of temperature from the bottom upwards.

If the salinity is uniform and the vertical distribution of temperature is isothermal, there will be a state of positive stability.

With uniform salinity and an adiabatic distribution of temperature the value of σ_t decreases slightly down-

wards without producing a state of instability. Some observations from the "Michael Sars" Expedition exhibited an increase of temperature and decrease of σ_t downwards in the deep water of the North Atlantic and gave rise to a renewed discussion of the adiabatic variations in the sea and to the introduction of the notion of potential temperatures in oceanography. It will therefore be appropriate to deal more fully with these problems here.

The adiabatic change of temperature may be computed by means of a formula by Lord KELVIN. When using the metre-ton-second system of units we have:

$$\delta\tau = 10^{-4}\int_a^b \frac{T.\ e.\ g.}{I.\ c_p}\, dz$$

Here T denotes the absolute temperature of the water $(273 + \tau)$, e the thermal coefficient of expansion, g the acceleration of gravity, I the mechanical equivalent of heat (0·419), and c_p the specific heat at constant pressure. The coefficient e varies considerably; it increases with increasing values of any of the elements: temperature, salinity or pressure. c_p is also variable.

Professor WALFRID EKMAN [1910, 1914] has published tables which make it easy to calculate the adiabatic effect in the case of sea-water. The following tables *A—D* have been compiled in accordance with the data given by EKMAN.

Tables A and B are calculated for sea-water with a value of $\tau_o = 28{\cdot}0$, corresponding to $S = 34{\cdot}85\ ^0/_{00}$, which is very nearly the salinity of the deep water in the great oceans and in the Norwegian Sea. Such deviations from $S = 34{\cdot}85\ ^0/_{00}$ as may occur in the deep strata of the oceans, have so little effect upon the value of the adiabatic variation that it amounts to less than 0·001° C. From Table *A* we may find the adiabatic cooling when the water is raised from a depth m to the surface. The argument τ_m means the temperature *in situ* at any particular depth [1]). Table *B* shows the adiabatic heating when the water is brought from the surface to the depth m. The argument τ_o means the temperature at the surface.

Table C is computed for salinities between 30·0 and 38·0 $^0/_{00}$ and temperatures between 0° and 22° C. The data are given for 1000 metres only, as such variations in salinity and temperature as are not covered by the two former tables are only found in the upper strata of the ocean (excluding areas like the Mediterranean and the Red Sea). For depths down to 1000 metres it makes practically no difference whether we use τ_m or τ_o as the argument ot temperature. The numbers printed in table *C* are averages of the numbers found by starting from 1000 metres (cooling) and those found by starting from the surface (heating). In any case the error only amounts to 0·001° C.

Table D, calculated for the deep water of the Mediterranean, is based upon a τ_o-value of 31·0 ($S = 38{\cdot}57\ ^0/_{00}$). The two halves of the table correspond to tables *A* and *B*.

From Tables *A—D* the value of $\delta\tau$ at any value of τ_m or τ_o may be found with sufficient accuracy by linear interpolation as far as the tabulated depths are concerned. For other depths the graphical tables Fig. 24 and 25 may be useful in connection with Tables *A* and *B*. The construction of the graphs is based upon a calculation of the correction to be added to the number found in the printed tables for the standard (some 1000 metres) level next above the level of observation. The diagrams are divided in several parts applicable for intervals of 1000 metres: from 1000 to 2000 metres, 2000 to 3000 metres and so on. Within each part, curves are drawn for every 50 metres; every second curve is numbered (from 1 to 9 dekametres). The scale of the initial temperature (τ_m or τ_o) is found along the abscissa, with sub-divisions for every 0·2°. The correction for the adiabatic variation is read along the ordinate, the numbers to the right and left in the figures being expressed in 1/100° C. Horizontal lines are drawn for every 0·001°. The use of the tables may be demonstrated by the following example, taken from observations in the Philippine Deep (cf. below):

At a depth of 9788 metres the temperature *in situ* (τ_m) was found to be 2·60° C. By means of Table *A* we find for 9000 metres and 2·60° by linear interpolation $\delta\tau = -1{\cdot}133°$. The graph in Fig. 24 gives for the remaining 788 metres between 9000 and 10000 metres and $\tau = 2{\cdot}60°$ an addition to $\delta\tau$ of $-0{\cdot}146°$, so that the final value of $\delta\tau$ is $-1{\cdot}279°$. If, therefore, the water is moved from 9788 metres to the surface the temperature would decrease adiabatically to $2{\cdot}60 - 1{\cdot}279 = 1{\cdot}321°$ C.

On the other hand, when water of $\tau_o = 1{\cdot}321°$ C. is moved from the surface to 9788 metres we find in Table *B*, 9000 metres: $\delta\tau = 1{\cdot}124°$, and in Fig. 25 an additional number $= 0{\cdot}155°$, or a total adiabatic variation of 1·279°, and hence a temperature at 9788 metres of $1{\cdot}321 + 1{\cdot}279 = 2{\cdot}60°$ C.

To find the temperature which water at a depth of a metres obtains adiabatically when moved to a depth

[1]) Professor SCHOTT published [1914] a table of the adiabatic variations of temperature from different depths to the surface. SCHOTT's data differ somewhat from those given here because he does not take into account that the temperature decreases all the time while the water is being drawn upwards; he regards the argument of temperature as a constant for all depths.

Within the interval of temperature between 0° and 4° C. the difference is about 0·055° for the depth of 10000 metres.

A. Adiabatic cooling $\left(\text{in } \frac{1}{100}\ {}^0\text{C.}\right)$ when sea-water $\left(\sigma_0 = 28{\cdot}0\right)$ which has a temperature of t_m at the depth of m metres, is raised from that depth to the surface.

m \ t_m	− 2°	− 1°	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
	—	—	—	—	—	—	—	—	—	—	—	—	—
1000	2·6	3·5	4·4	5·3	6·2	7·0	7·8	8·6	9·5	10·2	11·0	11·7	12·4
2000	7·2	8·9	10·7	12·4	14·1	15·7	17·2	18·8	20·4	21·9	23·3	24·8	26·2
3000	13·6	16·1	18·7	21·2	23·6	25·9	28·2	30·5	32·7	34·9	37·1	39·2	41·2
4000	21·7	25·0	28·4	31·6	34·7	37·7	40·6	43·5	46·3	49·1	51·9	54·6	57·2
5000	31·5	35·5	39·6	43·4	47·2	50·9	54·4						
6000	42·8	47·5	52·2	56·7	61·1	65·3	69·4						
7000			66·2	71·3	76·2	80·9	85·5						
8000			81·5	87·1	92·5	97·7	102·7						
9000			98·1	104·1	109·9	115·6	121·0						
10000			115·7	122·1	128·3	134·4	140·2						

B. Adiabatic heating $\left(\text{in } \frac{1}{100}\ {}^0\text{C.}\right)$ when sea-water $\left(\sigma_0 = 28{\cdot}0\right)$ which has a temperature of t_0 at the surface, sinks from the surface to a depth of m metres.

m \ t_0	− 2°	− 1°	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°
	+	+	+	+	+	+	+	+	+	+	+	+	+
1000	2·6	3·6	4·5	5·4	6·2	7·1	7·9	8·7	9·5	10·3	11·1	11·8	12·5
2000	7·3	9·1	10·9	12·7	14·3	16·0	17·5	19·1	20·7	22·2	23·7	25·1	26·5
3000	13·9	16·6	19·2	21·8	24·2	26·7	28·9	31·2	33·4	35·6	37·8	39·9	41·9
4000	22·4	25·9	29·3	32·6	35·8	39·0	41·9	44·8	47·7	50·5	53·4	56·1	58·7
5000	32·8	37·0	41·2	45·1	49·0	52·8	56·4						
6000	44·9	49·8	54·7	59·3	63·8	68·1	72·3						
7000		64·3	69·8	75·0	80·0	84·8	89·5						
8000		80·4	86·4	92·1	97·6	102·9							
9000		97·9	104·4	110·5	116·5	122·2							
10000		116·7	123·7	130·2	136·6	142·7							

C. Adiabatic variations of temperature (in 1/100°C.) for the upper 1000 metres of sea-water at different salinities.

$S\,^0/_{00}$	0° C.	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°
30·0	3·5	5·3	7·0	8·7	10·3	11·8	13·2	14·7	16·1	17·6	18·9	20·3
32·0	3·9	5·7	7·3	9·0	10·6	12·1	13·5	15·0	16·4	17·8	19·1	20·5
34·0	4·3	6·0	7·7	9·4	10·9	12·4	13·8	15·3	16·6	18·0	19·3	20·7
36·0	4·7	6·4	8·1	9·7	11·2	12·7	14·1	15·5	16·9	18·3	19·6	20·9
38·0	5·1	6·8	8·4	10·0	11·6	13·0	14·4	15·8	17·2	18·5	19·8	21·1

D. Adiabatic variations of temperature (in 1/100°C.) in sea-water of $\sigma_0 = 31{\cdot}0$.

m	t_m			t_0		
	12°	13°	14°	12°	13°	14°
	—	—	—	+	+	+
1000	14·4	15·1	15·8	14·5	15·3	16·0
2000	30·0	31·4	32·7	30·4	31·8	33·1
3000	46·6	48·6	50·6	47·4	49·4	51·4
4000	64·2	66·7	69·2	65·7	68·3	70·8

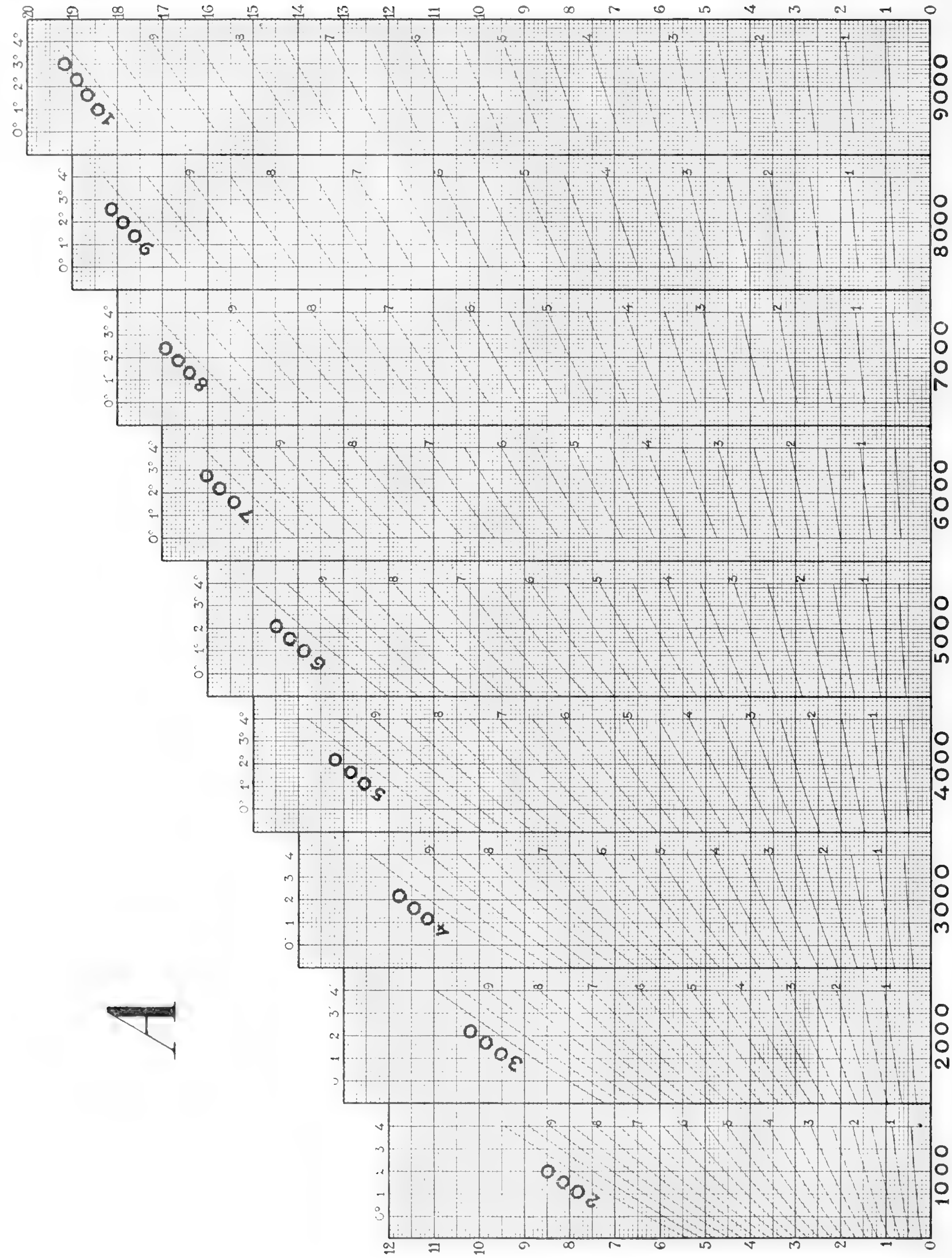


Fig. 21. Adiabatic variations. Corrections to be applied to Table *A* for depths between those found in this table.

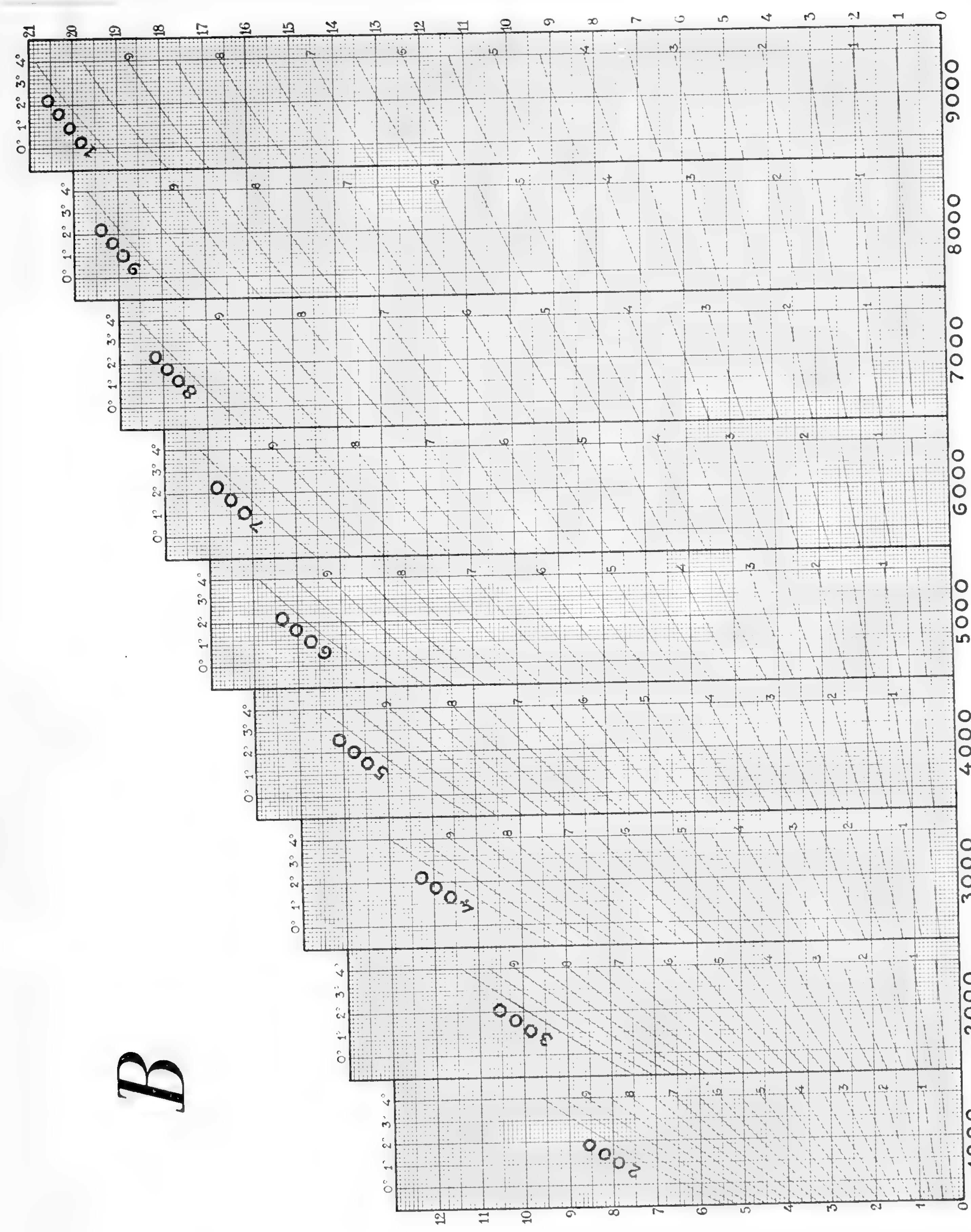


Fig. 25. Adiabatic variations. Corrections to be applied to Table *B* for depths between those found in this table.

of b metres, we can first, by means of Table A and Fig. 24, find the temperature which the water obtains when moved from a metres to the surface; and then, with the latter temperature as argument and by means of Table B and Fig. 25, find the change for a removal from the surface to b metres.

The temperature which the water attains adiabatically when the pressure is altered is called the *potential temperature* at the new pressure [HELLAND-HANSEN, 1912]. It may be detoned by Θ:

$$\Theta = \tau_m + \delta\tau$$

The removal may be indicated by means of indices in this way: when water with a temperature of τ_a at the depth of a metres is removed to a depth of b metres its potential temperature referred to the latter depth becomes:

$$\underset{a\to b}{\Theta} = \tau_a + \underset{a\to b}{\delta\tau}$$

The potential temperature referred to the surface (one atmosphere of pressure) is $\underset{a\to o}{\Theta}$.

We have:

$$\underset{a\to b}{\Theta} = (\tau_a + \underset{a\to o}{\delta\tau}) + \underset{o\to b}{\delta\tau'}$$

The values of $\underset{a\to o}{\delta\tau}$ and $\underset{o\to b}{\delta\tau'}$ are found in the tables. It must be emphasized that the argument for $\underset{a\to o}{\delta\tau}$ is τ_a, while for $\underset{o\to b}{\delta\tau'}$ it is $(\tau_a + \underset{a\to o}{\delta\tau})$.

In the deep part of the oceans the variations in salinity are so insignificant that they have no influence upon the compressibility. They are, therefore, of no consequence in determining the value of $\delta\tau$. In the case of adiabatic equilibrium between the levels a and b we have:

$$\tau_a = \underset{b\to a}{\Theta} = \tau_b + \underset{b\to a}{\delta\tau}$$

$$\tau_b = \underset{a\to b}{\Theta} = \tau_a + \underset{a\to b}{\delta\tau}$$

$$\underset{a\to o}{\Theta} = \underset{b\to o}{\Theta}$$

None of these equations hold good if the vertical variations of temperature do not correspond to an adiabatic equilibrium. As an example we may take some observations from great depths in the Pacific. G. SCHOTT [1914] has tabulated a number of observations from water near the bottom at various stations in the Philippine Deep and the New Pomeranean and the Bougainville Deeps, the observations from the two latter deeps being treated together. The observations are taken in 1907—1913 by means of reversing thermometers. SCHOTT has calculated the mean temperature at different levels. His results for depths of 5000 metres and downwards are quoted in the second column of the following table (τ_m). As these temperatures are not the results of serial observations along a vertical they do not claim to give an absolutely correct representation of the strictly *vertical* distribution of temperature. The chief result seems, however, to be quite certain: the temperature in these deeps increases vertically downwards from 5000 metres to the bottom. By means of Tables A and B and Figs. 24 and 25 we have computed the potential temperatures referred to the surface and to two other levels (a and b); the results are recorded im columns 3—5 of the table.

m	τ°_m	Θ° $m\to o$	Θ° $m\to a$	Θ° $m\to b$	$\Theta^\circ - \Theta^\circ_{min.}$ $m\to o$	$m\to a$	$m\to b$
1	2	3	4	5	6	7	8
The Philippine Deep ($a = 6000$, $b = 9788$)							
5000	1·50	1·047	1·642	2·310	0·031	0·032	0·033
6000	1·61	*1·016*	*1·610*	*2·277*	*0·000*	*0·000*	*0·000*
7000	1·80	1·048	1·643	2·311	0·032	0·033	0·034
8000	2·03	1·103	1·701	2·369	0·087	0·091	0·092
9000	2·32	1·203	1·805	2·475	0·187	0·195	0·198
9788	2·60	1·321	1·928	2·600	0·305	0·318	0·323
The Bougainville Deep ($a = 5000$, $b = 8400$).							
5000	1·81	*1·345*	*1·810*	*2·358*	*0·000*	*0·000*	*0·000*
6000	2·00	1·389	1·855	2·404	0·044	0·045	0·046
7000	2·23	1·457	1·926	2·476	0·112	0·116	0·118
8000	2·53	1·577	2·051	2·603	0·232	0·241	0·245
8400	2·66	1·631	2·107	2·660	0·286	0·297	0·302

In the *Philippine Deep* the salinity is uniform and equal to 34·68 ‰ from 5000 metres downwards, according to SCHOTT. In this Deep a minimum of temperature *in situ* is found at 5000 metres, while the values of Θ show a minimum at 6000 metres. This means that the water between 5000 and 6000 metres is in a state of positive stability. The values of Θ increase from 6000 metres to the bottom, which means a state of instability (an "overadiabatic" distribution of temperature). In columns 6—8 of the table above, the Θ-values for the water at 6000 metres in the Philippine Deep are subtracted from the corresponding values for the water at the other depths. We see that the differences given in the three columns are not the same. Comparing the water at 6000 metres (a) with that at 9788 metres (b) we find the following: when the water from both depths is raised to the surface the difference of potential temperature becomes 0·305°, while if referred to 6000 metres the difference is 0·318°, and if referred to 9788 metres it is 0·323°. We should have adiabatic equilibrium if the temperature at 6000 metres were 0·318° higher than it actually is,

and assuming the temperature at 9788 metres to be as observed (2·60°), or if the temperature at the latter depth were 0·323° lower than it is, with $\tau_a = 1{\cdot}61°$. In the first case ($\tau'_a = 1{\cdot}928°$, $\tau_b = 2{\cdot}60°$) we obtain $\underset{a\to o}{\Theta'} = \underset{b\to o}{\Theta} = 1{\cdot}321°$, and in the second ($\tau_a = 1{\cdot}61°$, $\tau'_b = 2{\cdot}277°$): $\underset{a\to o}{\Theta} = \underset{b\to o}{\Theta'} = 1{\cdot}016°$, the difference between these values being 0·305° or the same as is found between the two actual values of $\underset{m\to o}{\Theta}$.

The conditions demonstrated by the observations from the *Bougainville Deep* are analogous. Here the salinity is, also according to SCHOTT, uniformly equal to 34·69 ‰ between 5000 and 8400 metres. The minimum value of Θ is found at 5000 metres, and the state of "over-adiabacy" in the deeper layers is nearly the same as in the Philippine Deep. The following temperatures would give adiabatic equilibrium between 5000 and 8400 metres: $\tau_a = 2{\cdot}107°$ instead of 1·81° if $\tau_b = 2{\cdot}66°$ as observed, or $\tau_b = 2{\cdot}358°$ instead of 2·66° if $\tau_a = 1{\cdot}81°$ as observed. In the first case we have $\underset{a\to o}{\Theta} = \underset{b\to o}{\Theta} = 1{\cdot}631°$ and in the second $= 1{\cdot}345°$, the difference being 0·286°.

These examples show that except in cases of adiabatic equilibrium the differences found by a comparison of potential temperatures of different water-masses vary according to the pressure to which the potential temperatures are referred. It is convenient to take one atmosphere as the pressure of reference, and to calculate the values of $\underset{m\to o}{\Theta}$. *When nothing is stated to the contrary, potential temperature means the temperature which a water-particle attains when it is raised adiabatically to the surface of the sea.* A difference between two such potential temperatures does not show the exact amount by which either of the two temperatures observed has to be reduced in order to show adiabatic equilibrium. This point may be of some interest when deep-sea temperatures are determined within a few thousandths of a degree (as can now be done), but otherwise a comparison of potential temperatures referred to the surface is sufficient for our discussions of the temperature conditions in the deep waters of the oceans.

There are two main questions which arise in this connection: — 1. What is the temperature of the deep water before descending, if we assume that it is cooled somewhere at the surface and that its temperature alters on the way downwards merely as a result of adiabatic processes? Even if these assumptions do not actually hold good, it may be useful to compare the potential temperatures from different levels and stations so far as the deep water is concerned (cf. section 35). — 2. Is the deep water in a state of stability or not, if the temperature increases downwards and the salinity is uniform? On the latter assumption we have a state of stability until the vertical gradient of temperature reaches the adiabatic gradient. With a larger gradient of temperature *in situ* the conditions are instable and a vertical convection takes place.

Provided that the above-mentioned observations from the two deeps in the Pacific are nearly correct, we have here an example of instability which must be due to constant heating from the bottom. By means of these observations the virtual coefficients of friction and of temperature conductivity may be computed (both coefficients probably being in this case identical) as pointed out by W. SCHMIDT [1917] and more recently by HESSELBERG. It has been assumed that the salinity is uniform in these deep strata, but it is open to question whether this is true, even if the amount of chlorine be constant. In this connection it may be mentioned that probably the quantity of lime is comparatively great, and increasingly so downwards, in the deep parts of the ocean, making the total salinity and density somewhat higher than a titration of chlorine shows. Not impossibly, therefore, the density at the potential temperature and atmospheric pressure — which density may be termed the "*potential density*" — approaches uniformity at the depths in question. [1])

35. The Deep Water of the North Atlantic.

DEFANT [1928] has proposed to use for the different groups of water in the ocean a terminology analogous to that used for the atmosphere: the *troposphere* including the water-layers from the surface downwards as far as their temperatures exhibit vertical variations in any essential degree, and the *stratosphere* with but small variations of temperature. The uppermost part of the troposphere, on an average from the surface down to about 200 metres, is called the zone of variability ("Störungszone"). Such a grouping is very convenient, at any rate formally. It may sometimes be better to use the

[1]) In a paper just published, G. WÜST [1929] has discussed the observations from the Philippine Deep and the Bougainville Deep, and has corrected the values given by SCHOTT, quoted in the table above. According to WÜST the temperature in the Philippine Deep rises from 1·55° C. at 5000 metres to 2·48° C. at 9788 metres, while the salinity decreases from 34·68 to 34·66 ‰. From the Bougainville Deep WÜST finds at 5000 metres $\tau_m = 1{\cdot}97°$ C. and $S = 34{,}71$ ‰, and at 8400 metres $\tau_m = 2{\cdot}60°$ and $S = 34{\cdot}67$ ‰. These values mean a smaller deviation from adiabatic equilibrium than supposed in the discussion above, but the instability is much the same on account of the decrease downwards of salinity. My intention here, however, has only been to use the data as a formal example to elucidate some general principles, and for this purpose it is unnecessary to discuss the reliability of the absolute values of τ_m and S.

names *tropo-hydrosphere* and *strato-hydrosphere* in contradistinction to the corresponding terms for the atmosphere, but when no misunderstanding can arise the shorter names are sufficient.

Where to fix the limit between the troposphere and the stratosphere in the sea is more or less a matter of opinion. The vertical extension of the two spheres is very variable. In some small areas the troposphere may at times be absent, while in other regions it may reach 1000, or 2000 metres, or more, but in most cases the transition to the more uniform stratosphere is very gradual. For a special ocean we may agree in fixing a certain isotherm as the limit between the two spheres. In the Arctic and Antarctic regions as well as in the Norwegian Sea we may, for instance, take the isotherm of 0° C., in the Mediterranean that of 13° C. etc. With regard to the North Atlantic it seems reasonable to select the isotherm of 3° C. as a limit. In the greater part of this ocean 3° C. is found at depths between 2000 and 3000 metres below the surface. The water of the stratosphere, with temperatures below 3° C., is here called the *deep water*, although in some regions it may arise to high levels. But in the upper strata of this water there is a vertical gradient of temperature too, even if it generally is considerably less than in the lower part of the troposphere. What is here called the deep water is often called the *bottom-water,* but we shall use this therm only with reference to the lowermost water-layers, or to deep water where the temperature *in situ* is either uniform or increasing downwards. The bottom-water is thus synonymous with the deeper part of the deep water.

Quite a number of observations have been taken from the bottom-water (in combination with soundings), but until recently only very few vertical series have been secured from depths below 3000 metres. In 1921—22 the Danish expedition in the "Dana", and in 1925—27 the German expedition in the "Meteor" have worked a number of stations in the Atlantic with serial observations from great depths, but the observations are as yet only partly published. At present we possess, therefore, scanty material for studying the conditions in the real deep-water of the Atlantic, to say nothing of other oceans.

The deep water of the North Atlantic has, in the main, its origin in the northern regions of this ocean. After a discussion of the bottom-water and the cooling of the Ocean NANSEN [1912] summarizes his results in this way: "the bottom-water of the North Atlantic has a salinity of about 34·90 ‰ and temperatures about 2·4° C. It is chiefly formed at the sea surface in a limited area southeast of Greenland. It is also to some extent formed by water from the Norwegian Sea, flowing across the Faeroe-Shetland-Greenland submarine ridge".

The very salt and relatively warm water coming from the Mediterranean as an under-current through the Strait of Gibraltar is heavier than any water in the Atlantic and sinks here. In sinking it is mixed with Atlantic water. The mixed water attains such a density that the bulk of it is found at about 1000—1200 metres where the anomaly of salinity has a maximum, though at 2000 metres also the influence of the Mediterranean is very marked over wide areas in the eastern part of the North Atlantic. Even in the deep water at much greater depths such an influence may be traced by slightly increased salinities and temperatures.

On the other hand, deep water from the South Atlantic passes the equator and makes itself felt some way to the north, especially in the western part of the North Atlantic [BØHNECKE, 1927; WÜST, 1928]. The temperature and the salinity of the deep water are lower in the South Atlantic than in the North Atlantic.

In discussing the deep water of the North Atlantic we have, then, to pay attention not only to its chief source in the northern regions, but also to the arrival of water from southern latitudes and the effect of water from the Mediterranean.

During the "Michael Sars" Expedition only a few observations were taken from the deep water. Our observations at and over a depth of 3000 metres are grouped in the following table where Θ means the potential temperature (referred to the surface of the sea) and σ_Θ the corresponding density:

Stat.	Metres	τ_m ° C.	S ‰	σ_t	Θ	σ_Θ
10 A	3000	2·44	—	—	2·19	—
	4500	·555	—	—	·13	—
49 C	3950	2·42	34·90	27·878	2·07	27·907
	4950	·465	·90	·874	1·98	·915
63	3000	2.90	34.92	27·853	2·64	27·875
	4000	·355	·88	.867	·00	·898
	4850	·375	—	—	1·91	—
91	3500	2·63	34·965	27·912	2·33	27·937
	4000	·565	—	—	·20	—
	4750	·27*	·915	·903	1·82	·939

The stations 10 A, 49 C and 91 were situated in the eastern part of the North Atlantic (*i. e.* east of the central longitudinal ridge) and Stat. 63 in the western.

The temperature at Stat. 91, 4750 metres was observed by means of a NANSEN thermometer, fixed in the lid of a PETTERSSON-NANSEN insulating water-bottle (section 12). When the water-bottle arrived on deck, the temperature was 2·00° C., but is was rising and would certainly have

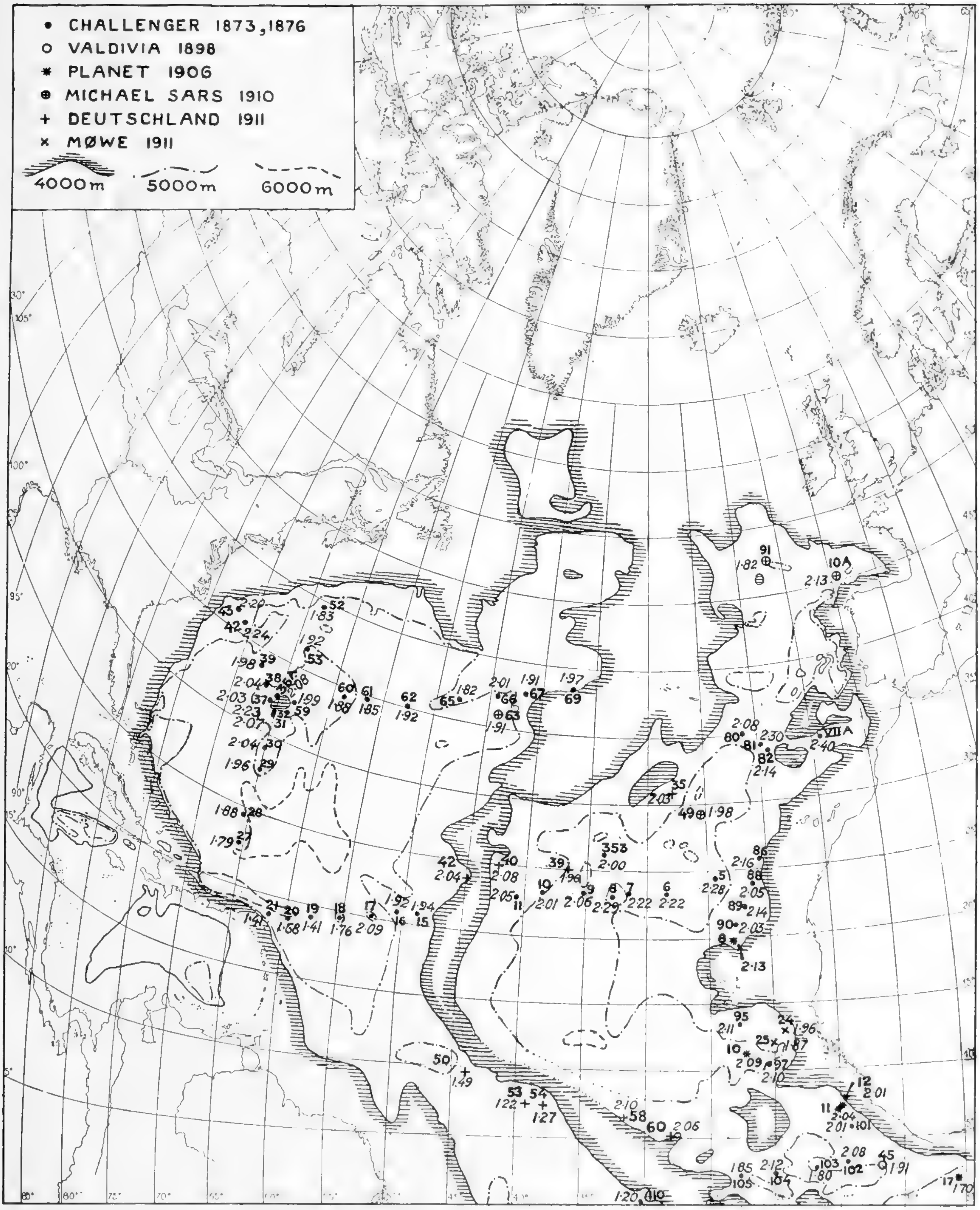


Fig. 26. Stations where the temperature near the bottom has been observed. The numbers represent the stations and the potential temperatures (not the temperatures *in situ).*

been lower if the insulating capacity of the water-bottle had been perfect. A temperature *in situ* of 2·27° corresponds very nearly to neutral equilibrium. Perhaps the temperature should be put lower still. In any case it seems certain that the temperature at this station decreased between 4000 and 4750 metres.

At the "Michael Sars" stations 10 A, 49 C and 63 the temperature *in situ* increased downwards at great depths. The determinations were made by means of Richter reversing thermometers, and the increase is greater than the error of observation.

From Stat. 10 A we have no determinations of salinity, but we have reason to believe that the salinity was uniform from 3000 metres downwards. At Stat. 49 C the salinity was 34·90 ‰ both at 3950 and at 4950 metres. At Stat. 63 the salinity at 4000 metres was a little lower (34·88 ‰) than at the two other stations. This agrees with the supposition that the deep water has a sligthly higher salinity in the eastern part of the North Atlantic than in the western. The salinity at 4850 metres at Stat. 63 was not determined, but probably it was the same as at 4000 metres.

Provided that $\frac{\partial S}{\partial z} = 0$ in the three cases where τ_m increases downwards, we may compare the potential temperatures from the point of view of adiabatic equilibrium. We then find that the temperatures *in situ* did not increase as much downwards as would correspond to adiabatic equilibrium. We had at all three stations a state of positive stability, however slightly developed. The vertical variation of potential temperature per 1000 metres was — 0·04° at Stat. 10 A, — 0·09° at Stat. 49 C and — 0·11° at Stat. 63. It may be that the differences between these values correspond to characteristic regional variations in the North Atlantic.

Temperatures near the bottom at great depths in the North Atlantic have been taken by several expeditions. Most of them are from the "Challenger" Expedition, the observations being made in 1873 and 1876 by means of the Miller-Casella maximum and minimum thermometers. These observations are not so accurate as observations with the modern reversing thermometers. The thermometers used on board the "Challenger" were mostly read in 0·1° F., but the instrumental error was probably greater in many cases, and the corrections applied are rather uncertain.

The principle of the Miller-Casella thermometers does not allow the registration of secondary maxima appearing at depths passed by the instruments when they are hauled up. A slight increase of temperature towards the bottom cannot be detected by these thermometers. Observations ostensibly taken near the bottom may, in reality, show a minimum of temperature occurring in the water at some distance above the bottom. In such cases the temperatures recorded as *bottom* temperatures are too low, if the observations are otherwise correct. For instance in the Philippine Deep where reversing thermometers — as mentioned in the previous section — showed an increase of temperature from 1·50° C. at 5000 metres to 2·60° at 9788, Miller-Casella thermometers would have uniformly shown 1·50° C. all the the way from 5000 metres down to the bottom. The bottom temperatures recorded by the "Challenger" Expedition cannot therefore be used for a discussion of the adiabatic variations in the deep parts of the ocean in the same way as the more modern observations from the Pacific deeps. It may be added, however, that the determinations of temperature from the "Challenger" Expedition seem otherwise, in the main, to be remarkably good.

The chart, Fig. 26, shows the position of the "Challenger" stations and some stations from other expeditions, where observations have been taken near the bottom at depths of 4000 metres or more. The four "Michael Sars" stations, referred to above, are also included. In the chart, isobaths are drawn for 4000, 5000 and 6000 metres. The central longitudinal ridge stands out very clearly, dividing the ocean at great depths into an eastern and a western region.

Fig. 27 exhibits the 'bottom temperatures' from depths below 4000 metres at the "Challenger" stations. The temperatures *in situ* (τ_m) are shown to the left in the figure, and the corresponding potential temperatures (Θ) to the right. The black dots refer to stations on the eastern side of the central ridge, and the crosses refer to stations on the western side. Stations south of 10° N. are omitted.

The latter figure shows that the temperatures of the bottom-water are generally higher in the eastern part of the North Atlantic than in the western. When we group the temperatures for some intervals of depth and calculate the averages (in C°), we find:

Metres	Eastern part		Western part	
	τ_m	θ	τ_m	θ
4000 to 4500	2·54	*2·15*	2·46	*2·04*
4500 to 5000	2.61	*2·14*	2·43	*1·97*
> 5000	2·70	*2·16*	2·29	*1·77*

The difference between the mean temperature *in situ* in the eastern part and that in the western part becomes more marked the deeper one goes. It is relatively small, about 0·1° C., at depths from 4000 to 4500 metres, in-

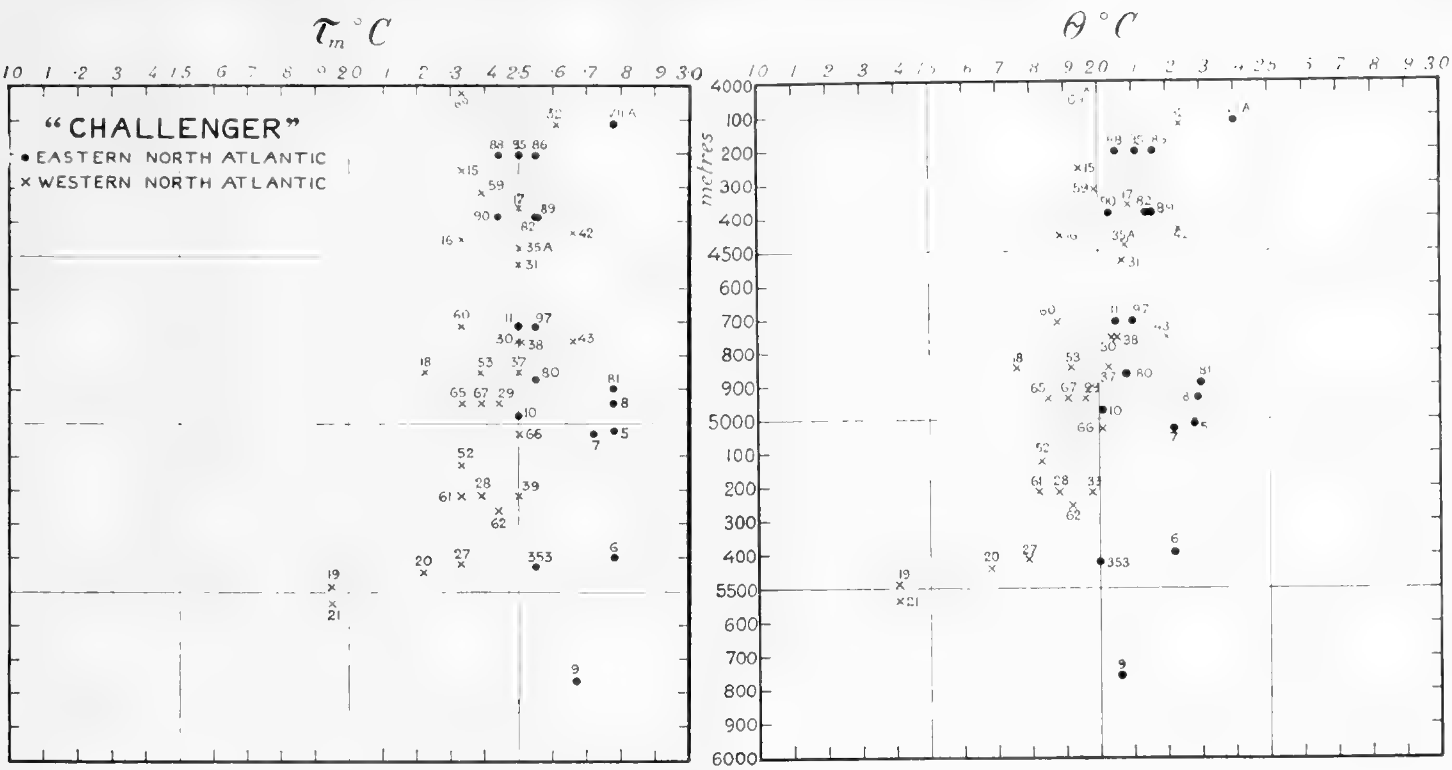


Fig. 27. To the left: temperatures *in situ* in the bottom water of the North Atlantic according to observations from the "Challenger" Expedition. To the right: potential temperatures corresponding to the temperatures observed.

creasing to 0·2° in the next interval of depth and to 0·4° at depths below 5000 metres. Similar variations are found in the potential temperatures.

With regard to the *eastern* part of the North Atlantic the mean temperatures *in situ* demonstrate an increase downwards which corresponds to adiabatic equilibrium (uniform potential temperatures). At first sight it might seem as if the observations here revealed, after all, conditions which were supposed not to be detectable by the Miller-Casella thermometers. Further consideration, however, lead to the conclusion that this apparent contradiction must be ascribed to regional variations.

The relatively high values of τ_m at depths between 4500 and 5000 metres and below 5000 metres are due to the observations from Stats. 5—9 and 81. Probably the bottom-water at these stations is influenced by water from the Mediterranean. The charts from 1000 and 2000 metres on p. 97*, demonstrating the distribution of salinity-anomaly, indicate the appearance of water mixed with water from the Mediterranean. As previously mentioned, such mixed water causes high positive values of $\triangle \mathfrak{S}$. The chart for 1000 metres shows maximum values in an area off the coast of Portugal, north of 35° N. At 2000 metres the values of $\triangle \mathfrak{S}$ are lower, but the maximum values appear in a belt more to the south-west, towards 30° N. It is very probable that the layer of $\triangle \mathfrak{S}_{max.}$ sinks farther to the south-west and that *vestiges of water from the Mediterranean appear in the bottom-water as far south as 25° or 20° N. Lat., and possibly still farther south.* The presence of this mixed water is indicated by comparatively high temperatures and salinities, but the deviation from the normal Atlantic conditions is more pronounced in salinity than in temperature. Even if high positive values of salinity-anomaly correspond to negative values of temperature-anomaly, the absolute values of temperature *in situ* are higher in such water than they are in the ordinary Atlantic water to which water from the Mediterranean has not been added. We shall return to this point in section 38 and only note here that very probably the high values of τ_m at the "Challenger" stations 5—9, at greater depths than 4500 metres, are due to the influence of Mediterranean water. This assumption is strengthened by sections published by WÜST [1928, Pls. XXXIII and XXXIV], showing, for instance, that at depths below 4000 metres a maximum of salinity appears in about 15—35° N. in the central part of the eastern North Atlantic.

In this connection it may also be noted that the temperature at the "Michael Sars" Stat. 10 A, 4500 metres, is relatively high. This station was worked in an area north of Cape Finisterre where water from the Mediter-

ranean is indicated quite distinctly at higher levels, as shown by the charts on p. 97*. In this respect there is a marked difference between the area near Stat. 10 A and that around Stat. 91, where the temperatures of the bottom-water seem to be considerably lower.

The conclusion to be drawn from this is, then, that the apparent increase of τ_m with increasing depth in the eastern regions is due to regional variations, and does not represent the distribution of temperature along a vertical.

Fig. 27 and the small table above indicate that, generally speaking, τ_m as well as Θ decrease with increasing depth in the *western* North Atlantic. It may be that the deep water is actually more stable in this part of the sea than on the eastern side of the central ridge. It is very doubtful, however, whether the apparent result of the "Challenger" observations corresponds to the real conditions. We see, for instance, that the observations at all "Challenger" stations between 30 and 39, at depths between 4480 and 5212 metres, show exactly the same temperature *in situ*, 2·50° C., with the exception of Stat. 32, where the depth is 4214 metres only and $\tau_m = 2.61°$ C.

It is possible that a minimum of temperature may occur at about 4500 metres in this area. Analogous conditions may be indicated in other areas too. In other words, it is possible that there may be a rise of temperature in the bottom-water in the western North Atlantic as well as in the eastern. The observations at the "Michael Sars" Stat. 63 actually show a slight increase of temperature between 4000 and 4850 metres. However this may be, it seems to be a fairly well established fact that the temperature of the bottom-water is higher, on an average, in the eastern than in the western North Atlantic.

The potential temperatures calculated from observations near the bottom at depths below 4000 metres are set out in the chart, Fig. 26. Most of them are due to the "Challenger" Expedition and are, therefore, as stated above, of doubtful reliability. They are apt to be too low, unless the minimum temperatures registered by the Miller-Casella thermometers are subject to systematic errors tending to give too high values. In any case, however, the data recorded by the "Challenger" in both parts of the North Atlantic are probably valid for mutual comparison and may serve to demonstrate the essential features of the local geographic variations in the bottom-water. The data procured by other expeditions and inserted on the chart, Fig. 26, seem to fit in quite well with the "Challenger" observations. Besides the deepest of the "Michael Sars" observations mentioned above, these data are as shown in the following table:

Expedition	Stat.	m.	$\tau°_m$	$\Theta°$
Valdivia 1898	45	4990	2·4	1·91
Planet 1906	8	4060	2·5	2·13
—„—	10 a	5124	2·6	2·09
—„—	10 b	5129	2·6	2·09
—„—	11	4743	2·5	2·04
—„—	12	4226	2·4	2·01
—„—	17	5138	2·2	1·70
Deutschland 1911......	35	4653	2·47	2·03
—„—	39	5108	2·46	1·96
—„—	40	4416	2·49	2·08
—„—	42	4274	2·43	2·04
—„—	50	4350	1·87	1·49
—„—	53	4836	1·66	1·22
—„—	54	4649	1·68	1·27
—„—	58	4143	2·48	2·10
—„—	60	4270	2·45	2·06
Møwe 1911	24	4288	2·35	1·96
—„—	25	4790	2·33	1·87

Some of the depths recorded for the "Deutschland" observations are uncertain, as the sounding wire was in some cases deflected rather far from the vertical.

Our chart (Fig. 26) demonstrates appreciable local variations of temperature in the bottom-water. In the eastern North Atlantic potential temperatures are found to be mostly above 2·0° C. In the southernmost parts, near the equator, some observations show lower values, with a minimum of $\Theta = 1·70°$ C. at the "Planet" Stat. 17. At the "Challenger" Stat. 103, where $m = 4526$ metres and $\tau_m = 2·22°$ C., Θ is 1·80° C. The low temperatures are due to water which comes from the western South Atlantic by way of a deep passage cutting through the central longitudinal ridge (the Romanche Deep), as suggested by SCHOTT and SCHULZ [1914] and proved by BØHNECKE [1927].

The "Challenger" station 104 ($m = 4572$ metres) was situated about 180 naut. miles W. of Stat. 103. The depths were nearly the same at both stations, but the temperatures observed near the bottom were different. At Stat. 104 τ_m was $= 2·55°$ C., the corresponding potential temperature being 2·12° C. At Stat. 102, about 132 miles E. of Stat. 103, we have $m = 4480$ metres, $\tau_m = 2.50°$ C and $\Theta = 2·08°$ C, or nearly the same temperature as at Stat. 104 on the other side of Stat. 103. Provided that the observations are fairly correct, we arrive at the important conclusion that *the temperature in situ of the bottom-water as well as the corresponding potential temperature may exhibit considerable variations in a horizontal direction even if the depth is greater than 4000 metres.* Similar examples are found by comparing, for instance, the "Challenger" stations 80 and 81, or Stats. 6 and 353 (cf. also the "Deutschland" station

15), or the "Michael Sars" stations 10 A and 91. These examples are taken from the eastern region, but something similar holds good for the western North Atlantic as well (cf. for instance the "Challenger" stations 19—21). We have not yet a sufficient number of determinations to examine the variations in salinity in the bottom-water. It is highly probable that the salinity exhibits horizontal differences which correspond to the differences of temperature, and that, accordingly, the densities are practically uniform. If not, there must be a field of force, which would mean that the velocity of the bottom-water is subject to vertical variations.

Bottom-water from the South Atlantic with relatively low temperatures spreads northwards on the western side of the North Atlantic. At the "Challenger" station 110 at the equator in about 30° W. the depth was 4160 metres and the temperature observed near the bottom 1·55° C. ($\Theta = 1{\cdot}20°$ C.). The temperature *in situ* and the potential temperature increase northwards as is seen from the chart, Fig. 26. The "Challenger" observations in abouth 20° N. (Stats. 15—21) seem to indicate that the cold bottom-water from the south exerts itself more strongly on the American side of the deep basin than along the central ridge. It is, however, impossible to draw safe conclusions from our material in this regard, on account of the inadequacy of the Miller-Casella thermometers and the lack of observations between 2743 metres (1500 fathoms) and the bottom. The depth to the bottom is less than 4500 metres at Stats. 15—17, but about 5500 metres at Stats. 19—21, and a water layer with a minimum of temperature may exist between these levels, as already stated.

It deserves notice that the apparent bottom-temperature observed was everywhere 2·5° C. or more at the "Challenger" stations between 30 and 43 where the depth to the bottom exceeded 4000 metres. Temperatures as high as these were observed at no other stations below 4000 metres in the western North Atlantic, with the exception of Stats. 17 and 66 and one of the "Deutschland" stations. They correspond to the potential temperatures above 2·0° C. (at Stat. 39: 1·98°) shown in the chart, Fig. 26. It seems natural to infer that the bottom-water below 4000 metres in an area west of about 65° W. Long. and north of about 33° N. Lat. is influenced by the Sargasso Sea in the same way that the bottom-water in the eastern North Atlantic appears to be affected by the Mediterranean.

We have hitherto chiefly discussed the temperature of the bottom-water at depths below 4000 metres. This water has to a great extent come from the northernmost part of the North Atlantic where the depths are smaller, and it must have, so to say, moved down hill. As mentioned above, the bottom-water of northern origin is mainly formed by the cooling of the sea surface in a limited area near Greenland, but partly also by a flow of cold water from the Norwegian Sea across the Faeroe—Iceland—Greenland Ridge at depths of, broadly speaking, about 500 metres. The latter water gets mixed with the water in the Atlantic in a similar way to the water coming from the Mediterranean across the ridge at Gibraltar.

The water near the bottom in the northernmost part of the North Atlantic exhibits great local variations in temperature and salinity, even at depths of 3000 metres and more. In the eastern part of the region in question, the temperatures *in situ* near the bottom at such depths are relatively high, between 2·5 and 3° C. This is evidently due to the influence of the Mediterranean even in these high latitudes. Some observations made during the "Armauer Hansen" Expeditions in 1913 and 1914 are quite illuminating. Stat. 6 in 1913 was taken in 54° 2′ N. and 24° 34′ W. The depth sounded was 3368 metres and the salinity of the water at the very bottom was 34·98‰. The lowest observation of temperature was secured from 3000 metres, where $\tau_m = 2{\cdot}83°$ C., $S =$ 34·97 ‰ and σ_t 27.90. In 1914 a station (62) was worked in 52° 47′ N. and 16° 39′ W. The deepest observation was taken at 3200 metres and gave $\tau_m = 2{\cdot}77°$, $S =$ 34·98 ‰ and $\sigma_t = 27{\cdot}91$. No sounding was made, but in all probability this observation was from a level not far above the bottom, to judge from the charts. $\tau_m = 2{\cdot}83°$ at 3000 metres correspond to $\Theta = 2{\cdot}57°$ and $\tau_m = 2{\cdot}77°$ at 3200 metres to $\Theta = 2{\cdot}49°$ C. These potential temperatures are, however, decidedly higher than those computed for the bottom-water at depths below 4000 metres in the eastern North Atlantic, so the water near the bottom at these two stations cannot directly form the bottom-water farther south in the ocean. The potential densities found from the observations in question are 27·920 and 27·934 respectively. At the "Michael Sars" Stat. 91 in about 47½° N. the observations from 3500 metres gave: $\tau_m = 2{\cdot}63°$, $S = 34{\cdot}965$ ‰, σ_t 27·91, $\Theta = 2{\cdot}33°$ and $\sigma_\theta = 27{\cdot}937$. This fits in very well with the observations from 3200 metres at the "Armauer Hansen" Stat. 62, when the difference of depth is taken into account. This water does not belong to what we have called the bottom-water in our discussion above, but to a higher layer in the deep water. At the "Michael Sars" station 91, 4750 metres, the salinity observed was just what must be expected for the bottom-water in the eastern North Atlantic, 34·915 ‰, with a temperature *in situ* estimated at 2·27 ° C. and a corresponding potential temperature of 1·82 ° ($\sigma_\theta = 27{\cdot}94$). Water of the same salinity and potential temperature was not observed at the above-mentioned stations 6 and 62 of the "Ar-

mauer Hansen". It obviously did not exist at the former station, as the salinity at the bottom was as high as 34·98 ‰. At the other station it may have existed in a relatively thin sheet between 3200 metres and the bottom, but that is not probable when we consider that this station (62) is situated much farther to the east than Stat. 6. In this case, and provided that considerable temporal changes do not take place in the deep water, the bottom-water of northern origin appearing in the eastern part of the North Atlantic does not come from due north, but from regions more to the west.

During the "Ingolf" Expedition in 1895 [KNUDSEN, 1898], 5 stations were worked along a curved line from SE to W of Cape Farewell, at a distance of between 120 and 160 nautical miles from land. The following table gives the results of observations near the bottom at these stations:

Stat.	Lat. N	Long. W	m	t_m° C.	θ° C.	S ‰
20	58° 20′	40° 48′	3192	1·5	1·26	34·97
21	58° 1′	44° 45′	2505	2·4	2·20	34·72
22	58° 10′	48° 25′	3474	1·4	1·13	34·96
38	59° 12′	51° 5′	3521	1·3	1·03	34·60
37	60° 17′	54° 5′	3229	1·4	1·15	34·63

At the time of the "Ingolf" Expedition the methods of determining the salinity were not nearly as exact as they are nowadays, and the salinities cited above cannot be expected to satisfy our demands with regard to accuracy in dealing with the bottom-water of the oceans, although, on the whole, KNUDSEN's determinations are remarkably good. The salinity of the bottom-water found at Stat. 21 should probably have been about 34·90, as 34·94 was observed at 1695 metres with a temperature *in situ* of 2·9° C. Similarly, the salinities found at Stats. 38 and 37 are certainly too low.

The temperatures from the "Ingolf" were determined by means of reversing thermometers. In general they are probably too low, because they are not corrected for the heating of the severed column of mercury, and the temperatures of the surface waters and the air were much higher than those of the deep water. At any rate, the bottom-temperatures recorded at depths below 3000 metres are much lower than those found in the deepest bottom-water of the North Atlantic.

The table above shows temperatures (t_m as well as θ) which decrease fairly regularly with the depth.

WÜST [1928] suggests that a ridge, which he calls the Newfoundland Ridge, connects the Newfoundland Bank with the central longitudinal ridge of the North Atlantic, and thus forms the southern limit of a deep called "The Labrador Deep". This does not appear from our bathymetrical chart on p. 63*, but is indicated on Fig. 26. In his sections (*l. c.* Pls. XXXIII and XXXIV) WÜST indicates that the depth of the Newfoundland Ridge below the surface is about 3000 metres. It is very probable that the deep water below this depth in the sea south of Greenland is shut off from the deep water in lower latitudes. In this case we must look for the chief northern source of the bottom-water of the North Atlantic Ocean at levels above 3000 metres. The observations from the "Ingolf", cited above, seem to show that such water existed between 2500 and 3000 metres in the sea south of Cape Farewell.

In his above mentioned paper in 1913 NANSEN reproduces two charts (*l. c.* Figs. 8 and 9) illustrating the conditions at the surface of the sea between the British Isles, Greenland and Newfoundland in April. He defines an area where the conditions seem to be specially favourable for the formation of bottom-water, with temperatures of about 2° C. and salinities of about 34·9 ‰. The Danish Meteorological Institute has constructed isotherms for the mean monthly temperatures of the surface of the sea north of 50° N., based upon observations from 1876 to 1915. There are only a few observations made in winter in the northwesternmost parts of the Atlantic, so the isotherms can only be drawn approximately. There is no doubt, however, that temperatures of about 2° C. appear at the surface over quite long stretches outside the drift-ice along southern Greenland in winter, when no ice-melting takes place and the salinity is, presumably, relatively high in these regions. From what may now be deduced it seems very probable that salinities of about 34·9 ‰ here coincide with temperatures varying between, say, 1° and 3° C.

We have, unfortunately, no vertical series with observations of temperature and salinity from the areas in question in winter, but we may safely conclude that an extensive vertical convection must take place where the surface waters have attained such high densities as result from temperatures of 1°—3° C and a salinity of 34·9 ‰. The heaviest, *i. e.* in this case the coldest, water will sink deepest. We must then assume that the coldest water follows the deepest parts of the sea-bed and collects in the Labrador Deep (an excess being carried away by mixing with the water above) while water with a potential temperature of around 2° C. occurs at higher levels and spreads southwards. It may move across the Newfoundland Ridge to the western part of the North Atlantic, or eastwards, south of the Reykjanes Ridge (see the bathymetrical chart, p. 63*) to the eastern part. It is very probable that considerable annual variations may occur in the temperature as well as in the quantity of the

bottom-water coming in this way to the Atlantic Ocean from the north, but we have no observations for studying this question. That there must be a seasonal variation, with a maximum flow of bottom-water after the winter cooling, is *a priori* most probable.

We know practically nothing of the movements of the deep water. Quite generally we may infer that the bottom-water in the greater part of the North Atlantic moves with a component towards the south, but nothing definitely can be stated with regard to velocities. We possess too few trustworthy determinations of salinity (density) from the bottom-water, and lack vertical series of observation from great depths. No dynamic calculations of any value can be made.

36. The Horizontal Distribution of Temperature in the Troposphere.

If there were no currents in the sea, isotherms representing the mean annual temperatures would go in an almost east-west direction and be evenly distributed, with some relatively small deviations due to variations along the parallels in the balance of gain and loss of heat. The large and often irregular horizontal variations actually existing in the North Atlantic and in other oceans, with isotherms going in many directions and with very variable horizontal gradients of temperature, are mainly due to currents. When we disregard the pure wind-current at the surface, we may state as a general rule, that *the greater the horizontal variations of temperature are, the stronger are the currents, and vice versa.* We have, then, to consider the variations not only at a certain level, but at higher and deeper levels as well. The validity of the rule is due to the fact that the variations in temperature coincide, on the whole, with variations in density.

In places where the horizontal variations of temperature are relatively large, therefore, the transport of water is also relatively large, with a quick conveyance of its content of heat, as well as of its other constituents such as salt, plankton organisms etc. In order to illustrate this we may refer to the charts for 100, 400 and 600 metres on p. 96*. They show a crowding of the isotherms especially in a belt which exactly corresponds to the site of the Great Atlantic Current. In regions where the horizontal gradient of temperature at all levels is relatively small, the water moves but slowly. This connection between the distribution of temperature and the currents has already been mentioned above (pp. 21 and 36), and it will be further explained in the chapter on the dynamics of the sea.

According to a law of "parallel solenoids", we find that the isotherms generally run parallel at the various depths, when we make proper allowance for the vertical variations of temperature. This means that *temperature charts of different levels resemble each other when we disregard the absolute values of temperature and the variable number of isotherms.* The resemblance is clearly seen in the charts on p. 96* when we except the regions where water from the Mediterranean appears and makes the conditions so peculiar that the parallelism is blurred. We see, for instance, that the isotherm for 8° C. at 100 metres has very nearly the same course as the isotherm for 6° C. at 400 metres and for 5° C. at 600 metres. In the deeper strata comparatively few isotherms appear, and the really deep water is nearly homotherm in a horizontal direction over wide stretches.

The conditions mentioned here are evidently of considerable significance for marine zoo-geography. *It may be assumed that the biological limits are nearly parallel at different levels above the deep water*, though the communities of animal organisms may vary from one level to another.

It has been observed that there is often a certain resemblance between the horizontal distribution of temperature (and salinity) even at the surface of the sea and the topography of the sea-bottom. This is a consequence of the law of "parallel solenoids" just mentioned, in combination with another general law discovered by W. Ekman. This law tells us that a gradient current which flows in a direction where the depth to the bottom decreases, turns *cum sole (i. e.* to the right in the northern hemisphere and to the left in the southern). The current turns in the opposite direction when the depth to the bottom increases. This holds good even if the depths are very great. The isotherms must, then, exhibit similar bends. This will explain, for instance, the characteristic features of the temperature charts in the vicinity of the Newfoundland Banks. The "Gulf Stream" coming from the south-west meets the slope S. of the Banks where the bottom-depth decreases, and makes a turn to the right. Then the current passes a locality with increasing depths, and turns to the left. Later on, it turns again to the right, and finally continues across the ocean. Our small-scale charts (p. 96*) are not supposed to show the variations in detail. In fact, these cannot be studied at present, except in a few places, because the observations from most regions are inadequate. We may, however, point out that the horizontal distribution of temperature must exhibit great local variations in areas where the currents are fairly strong and the depth to the bottom of the sea varies. *The unevenness of the sea-bed affects the distribution of temperature (and salinity etc.) upwards through the water to the surface.*

The charts on p. 96* are rather schematic, even for those parts of the eastern North Atlantic where relatively

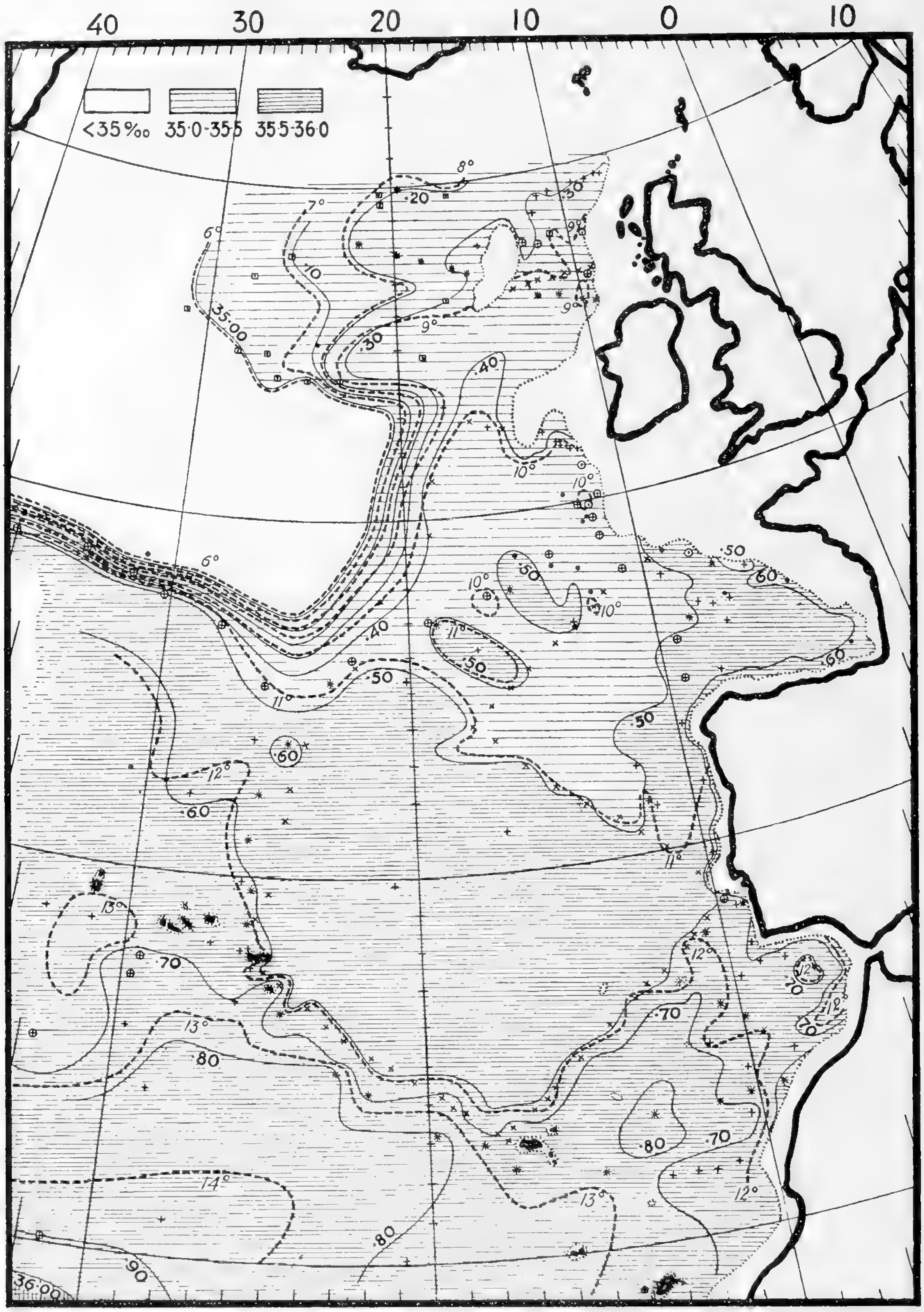


Fig. 28. Temperature and salinity at 400 metres below the surface in the eastern North Atlantic [HELLAND-HANSEN and NANSEN, 1926, Pl. 40].

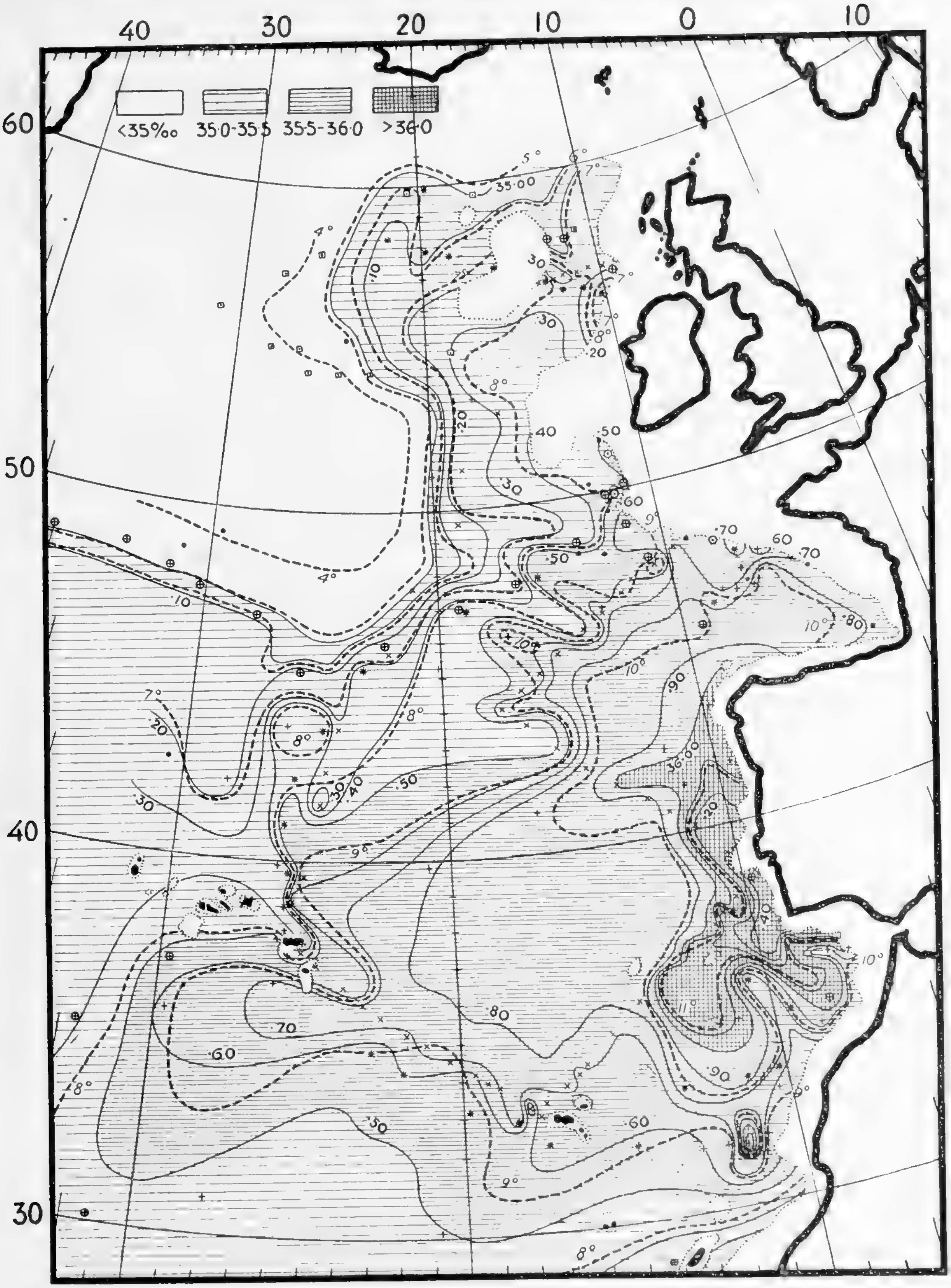


Fig. 29. Temperature and salinity at 1000 metres below the surface in the eastern North Atlantic [HELLAND-HANSEN and NANSEN, 1926, Pl. 46].

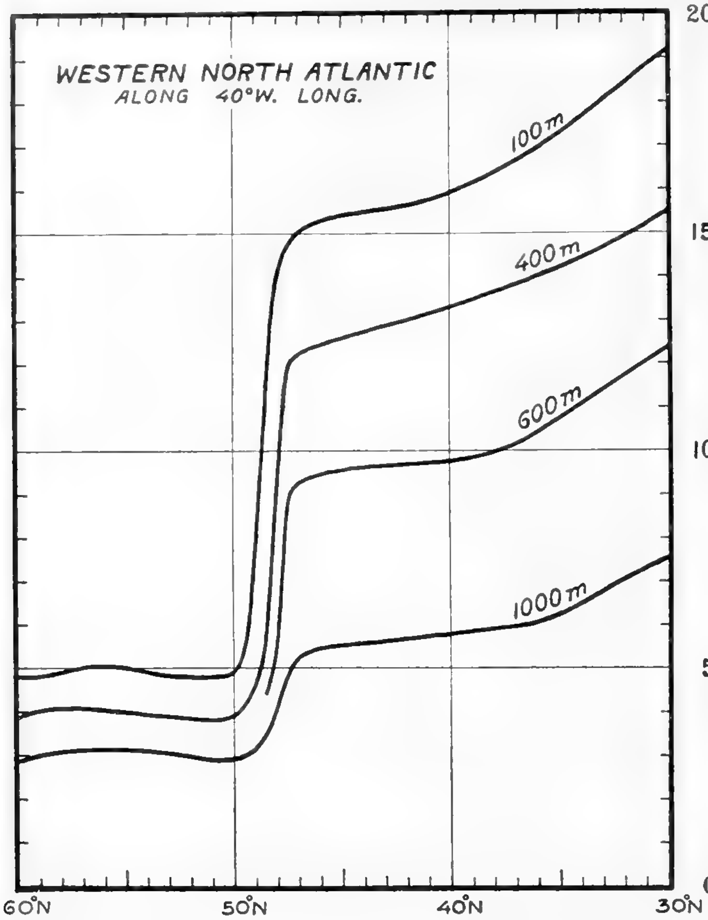


Fig. 30. Temperatures at 100, 400, 600 and 1000 metres below the surface along 40° W. from 60° to 30° N. (the western North Atlantic).

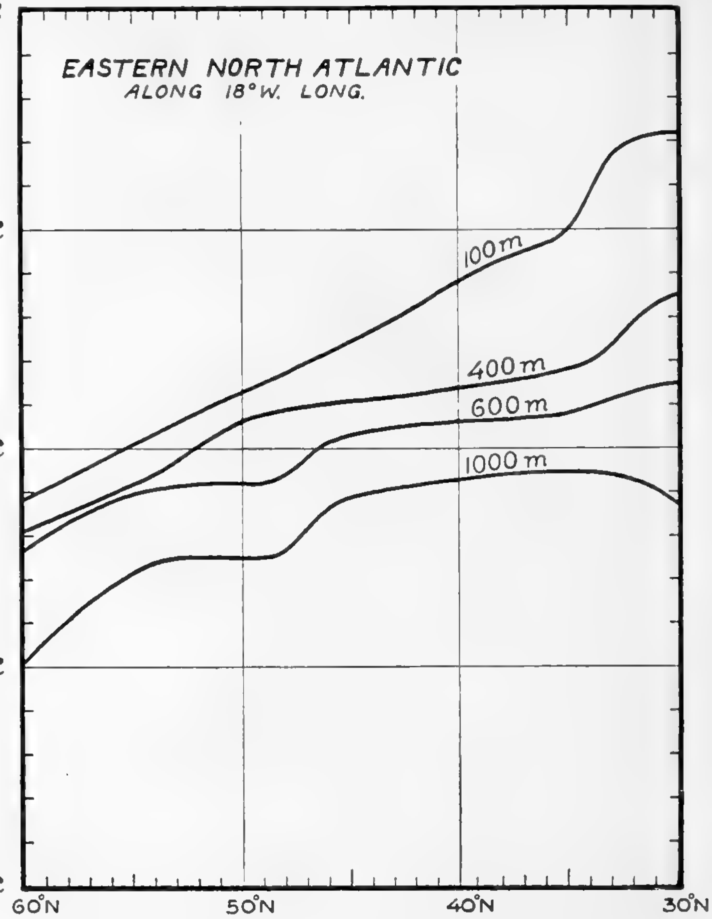


Fig. 31. Temperatures at 100, 400, 600 and 1000 metres below the surface along 18° W. from 60° to 30° N. (the eastern North Atlantic).

numerous serial observations have been made. Since these charts were printed Professor Nansen and I have constructed some charts in greater detail. They are published in "The Eastern North Atlantic", and two of them, for 400 and 1000 metres, are reproduced here in Figs. 28 and 29. We have made use of all the available modern observations, and have taken them as they are, without trying to reduce them for possible temporal variations (cf. p. 59). The "Michael Sars" stations are marked thus: ⊕. Figs. 28 and 29 show a number of differences from the corresponding charts on p. 96* as far as details are concerned. The new charts will certainly have to be corrected in many particulars when more observations have been made. There are still considerable areas where practically no stations have been worked and the question is whether the conditions here are complicated in much the same way as in the localities where the stations lie comparatively close together.

It seems unnecessary to describe the temperature charts in more detail. There are only one or two facts of a general nature which seem worthy of special notice:

The Great Atlantic Current forms, so to speak, a line of demarkation at all levels down to 1000 metres or more. We have only a limited number of observations from quite a large region S. of Greenland, but we have reason to believe that the whole of this part of the North Atlantic, on the northern and western side of the current, constitutes a cold area clearly distinct from a warm area on the southern and eastern side. When we cross this important current we pass from one 'world' to another as regards temperatures, and the transition is very abrupt — probably even more so than is shown in the charts on p. 96*.

The conditions in the *western* part of the North Atlantic are illustrated quite schematically in Fig. 30, which shows the horizontal distribution of temperature along the meridian of 40° W. from 60° to 30° N. Within a belt of about 200 kilometres (or about 2 degrees of latitude) in width we have a transition in temperature which is remarkably abrupt: at 100 metres below the surface about 10° C., at 400 m. 8°, at 600 m. 5° and at 1000 m. 2° That there is a division in a cold area to the north and a warm area in the central parts of the North Atlantic is, of course,

well known, but such a sudden transition as our charts and figures suggest has evidently not been perceived before. It must be admitted, however, that we posses no serial observations along sections straight across the Great Atlantic Current, so it cannot be directly proved that the transitions are as sudden as stated here, but the "Michael Sars" observations strongly support our view, which is further strengthened by dynamical calculations. It is probable that the horizontal gradient of temperature is smaller at the surface than at some intermediate depths, and it is possible that the abruptness of the transition has been exaggerated as far as the 100 metres level is concerned, but scarcely with regard to the deeper levels.

The conditions in the *eastern* part of the North Atlantic are more complicated than in the western part as has repeatedly been mentioned. The Great Atlantic Current is split up in several branches. One of these goes northwards, so that the sea east of about 20° W. is warm even N. of 50° N., as compared with the sea further to the west. Fig. 31 illustrates the horizontal distribution of temperature along the meridian of 18° W., from 60° to 30° N. The curves are smoothed. They do not show all the local variations represented in Figs. 28 and 29, but only the main features. The curves demonstrate clearly the following conditions between 60° and 30° N. In the northern region the temperatures are much higher in the eastern part of the North Atlantic than they are in the western part at all depths between the surface and 1000 metres (the same holds good of greater depths too). In the southern regions (S. of about 48° N.) the conditions are reversed as far as the upper 500 metres are concerned, but from 600 metres downwards it is warmer in the eastern than in the western part of the sea. The latter phenomenon is accounted for by the influence of the Mediterranean upon the Atlantic. The same influence explains the fact that the difference in temperature between 400 and 1000 metres is much smaller in the eastern areas than in the western (about 3° C. against 7°), and that the vertical gradient of temperature deeper down, when approaching the deep water, is much greater in the former areas than it is in the latter (cf. section 37).

37. The Vertical Distribution of Temperature.

The vertical variations of temperature are, on the whole, much greater than the horizontal. We have discussed the variations in the deep water in section 35 and shall here deal only with the troposphere of the North Atlantic. In nearly all regions the maximum temperature is at the surface and the minimum in the deep water, so the total vertical variation of temperature within the troposphere is generally equal to the surface temperature minus 3°. This total variation reaches its maximum in the tropics, corresponding on an average to about 1° C. per 100 metres. It decreases with increasing latitude and may be subject to considerable seasonal variations.

We shall only deal here with a few general considerations. In the following discussion we shall use the expression *mean variation* to denote the average vertical variation of temperature in 1/100° C. per metre (or whole degrees per 100 metres) between two levels $\left(10^2 \frac{\Delta t}{\Delta z}\right)$. When we reckon the positive depths downwards, the mean variation is generally negative, as the temperature usually decreases with increasing depths.

In some regions the temperature may become nearly uniform from the surface down to several hundred metres at the end of the winter cooling. With perfect mixing the mean variation will become slightly positive on account of the adiabatic effect, which may be calculated by means of the tables in section 34, p. 67. At medium latitudes in the North Atlantic the adiabatic rise of temperature downwards will only amount to about 0·01° C. per 100 metres (the mean variation about 0·01) and may therefore be neglected.

On the "Michael Sars" Expedition some stations were worked in April in the sea S. of Ireland. At Stats. 4, 7, 8 and 9 the difference of temperature between the surface and 200 metres was from 0·30 to 0·35° C., and the mean variation, on an average, — 0·17. Between 200 and 400 metres the mean variation only amounted to between — 0·03 and — 0·08, the average being — 0·06. At 200 metres the temperature ranged from 10·25° to 10·65° C. at the stations in question, and at 400 metres from 10·10° to 10·52° C. It is very probable that the vertical convection in winter (March) in this region extended to such a depth that the temperature was uniform from the surface to 400 metres or more. Even if the seasonal variations are small below 200 metres (cf. section 32), some propagation of heat from above may take place in early spring when the virtual coefficient of temperature conductivity is relatively great because the water-masses are almost in a state of neutral equilibrium. Stat. 93 was worked in the same region on the 25th of July. At this station the difference of temperature was 4·72° C. between the surface and 200 metres. At 200 metres the temperature was 10·38° and at 400 metres 10·24° C., the mean variation between these depths thus amounting to — 0·07. This variation and also the temperatures themselves were practically the same as at the stations in April.

In our area "B", off the Bay of Biscay (Fig. 11), so many stations have been worked that we may attempt a computation of the average differences of temperature from level to level at various seasons, and find the correspond-

Mean date	No. of obs.	0—25 m.	25—50 m.	50—100 m.	100—200 m.	0—200 m.
		$\Delta\tau$ (var.)	$\Delta\tau$ (var.)	$\Delta\tau$ (var.)	$\Delta\tau$ (var.)	$\Delta\tau$ (var.)
April 18	6	0·20 (– 0·8)	0·12 (– 0·5)	0·10 (– 0·2)	0·14 (– 0·1)	0·56 (– 0·3)
May 14	5	1·38 (– 5·5)	0·36 (– 1·4)	0·27 (– 0·5)	0·18 (– 0·2)	2·19 (– 1·1)
June 8	19	0·18 (– 0·7)	1·36 (– 5.4)	0·87 (– 1·7)	0·46 (– 0·5)	2·87 (– 1·1)
July 18	8	0·61 (– 2·4)	3·42 (– 13·7)	1·20 (– 2·4)	0·50 (– 0·5)	5·73 (– 2·9)

ing mean variations. In so doing we must use observations from several years and neglect the changes from one year to another. The result of such a computation is given in the table above. The stations used are grouped about the middle of April, the middle of May, the first half of June and the middle of July (cf. Fig. 15). The mean dates are noted in the table, as well as the number of observations. The temperature at the upper level minus that at the lower has been computed for each station, the average of such differences being given in the columns headed $\Delta\tau$. Numbers showing the mean variations are printed in brackets.

The vertical variation of temperature between the surface and 25 metres is very irregular. The observations in May were taken in 1911 and 1922; in the latter year especially they showed a considerably higher temperature at the surface than at 25 metres. Observations at 12 stations, between the 5th and 12th of June, 1911, showed, on the other hand, a lower temperature at the surface than at 25 metres. After a gale the temperature difference between the two levels is generally very small even in summer.

The difference of temperature and the mean variations below 25 metres progress very regularly in space and time. The vertical variations of temperature have a maximum between 25 and 50 metres in spring and summer. The above computations show a mean difference of 0·14° C. per metre in the middle of July in area "B". This difference is evidently still greater at the end of August.

The conditions alter from region to region, but the chief characteristics of the upper water-layers, shown in the example from area "B", are valid for most of the North Atlantic: there are small values for the mean variation from the surface down to 20 or 25 metres even in summer; at a short distance below this depth there are values that increase numerically all the time during spring and summer and reach an absolute maximum (in the warm season they are higher than anywhere else along the vertical from surface to bottom); while below some 50 to 75 metres the values decrease numerically downwards to a minimum which is met with at varying depths.

The vertical convection in winter, resulting in uniform temperatures from the surface downwards, attains very different depths in the different parts of the sea. We have in winter very few observations. On the "Challenger" Expedition serial observations were made in the latter half of February, 1873, at Stats. 4, 5, 8 an 10 across the deep eastern part of the North Atlantic in 25—23° N., and in the first half of March at Stats. 15, 17, 18 and 20 across the deep western part in 21—19° N. At all these stations observations were made at the surface, 100, 200, 300 fathoms and so forth. When interpolating for metres instead of fathoms we get the following averages of $\Delta\tau$ (in °C.) and mean variation:

	0—200 m.	200—400 m.
	$\Delta\tau$ (var.)	$\Delta\tau$ (var.)
"Challenger" 4—10	2·4 (— 1·2)	3·9 (— 1·9)
—„— 15—20	3·4 (— 1·7)	4·9 (— 2·4)

The vertical variation of temperature between the surface and 200 metres is much greater here than was shown above for the area "B" in April (when the heating of the surface had commenced) and even greater than in May. At the first 4 "Challenger" stations mentioned observations were not made between the surface and 100 fathoms except at Stat. 10, where the following temperatures were observed:

depth:	0	10	20	30	40	50	60	70	80	90	100 fathoms
τ:	21·7	22·1	22·1	22·1	22·0	21·9	21·8	21·4	20·7	20·1	19·4° C.

Even if the surface is further cooled during several weeks, it is not likely that the winter convection will go deeper than 70—80 fathoms or about 150 metres. There are no determinations of salinity so the stability cannot be examined.

At Stat. 18 in the western part of the North Atlantic the temperature was observed at 50 fathoms, being here 23·0° C. while it was 23·3° C. at the surface and 21·0° at 100 fathoms. At this stations the vertical convection in winter would scarcely extend to as much as 100 metres below the surface.

In the North Atlantic near the equator the annual range of temperature has a minimum (Fig. 9). In a region where the mean range is less than 2° C. and, in part, less than 1°, observations were made in the middle of July

1911 during the "Deutschland" Expedition [BRENNECKE, 1921]. The temperatures observed in the upper 400 metres are recorded in the following table, which gives also the mean variations (in brackets).

Stat.	53	55	57	60	61
Lat. N.	7° 30′	7° 13′	6° 45′	5° 8′	2° 40′
Long. W.	39° 16′	36° 1′	33° 25′	28° 3′	28° 7′
0 m........	26·86	27·22	27·16	26·83	25·72
		(– 3·0)	(– 0·8)	(– 0·1)	
25 „	—	26·47	26·95	26·80	—
		(– 7·6)	(– 4·8)	(– 0·0)	
50 „	26·67	24·57	25·75	26·80	25·74
	(– 3·4)	(– 16·4)	(– 9·1)	(– 0·5)	(– 0·7)
75 „	25·81	20·47	23·47	26·68	25·56
	(– 29·0)	(– 19·5)	(– 12·1)	(– 32·0)	(– 12·8)
100 „	18·57	15·59	20·45	18·67	22·37
	(– 11·8)	(– 6·5)	(– 16·0)	(– 9·0)	(– 14·8)
150 „	12·65	12·32	12·46	14·19	14·98
	(– 3·8)	(– 3·5)	(– 4·5)	(– 3·4)	(– 2·9)
200 „	10·71	10·55	10·21	12·50	13·53
	(– 1·5)	(– 1·2)	(– 1·0)	(– 1·5)	(– 2·4)
400 „	7·70	8·15	8·20	9·44	8·72

It is probable that the effective vertical convection in these low latitudes does not go deeper than 80—90 metres and in places not even as deep as this. The highest numerical values of the mean variation are found here at a greater depth than farther north.

In coastal waters and in areas where Arctic water covers the Atlantic water, the vertical variations of salinity, and consequently the stability, may be so great that the winter convection is limited to a relatively thin layer. In such areas the vertical variations of temperature may be very great in summer. Our stations on the Newfoundland Bank show that the vertical variations of salinity are small in the surface layer down to 10—25 metres, and very great below this layer. We find the following mean variations of temperature at the "Michael Sars" stations at the Newfoundland Bank and the Flemish Cap:

Stat.	70 A	71	72	73	74	76	77	79
0— 10 m.	– 7·0	– 2·7	– 1·2	– 2·8	– 2·5	– 6·5	– 7·2	– 13·5
10— 25 „	– 16·0	– 10·2	– 1·2	– 5·8	– 4·2	– 7·7	– 2·7	– 9·7
25— 50 „	– 20·2	– 18·3	– 32·9	– 27·8	– 23·8	– 17·0	– 19·1	– 14·2
50— 75 „	+ 8·2	+ 4·1	0·0	—	– 8·0	+ 2·2	– 0·3	– 0·4
75 – 100 „	+ 3·0	+ 0·8	—	—	+ 0·8	+ 2·9	– 1·5	– 0·4
100—150 „	+ 1·2	+ 0·7	—	—	+ 0·9	+ 2·1	+ 2·4	– 0·5
150—200 „	+ 0·8	—	—	—	—	+ 1·4	—	+ 1·1

At all these stations there is a maximum vertical variation of temperature between 25 and 50 metres, with an inversion of temperature somewhere below 50 metres.

The vertical gradient of temperature is, of course, greater at some levels and may be much greater than the mean variation. For instance, at Stat. 72, 30 metres $10^2 \frac{\partial t}{\partial z}$ is about — 100.

At Stats. 73—76 incl. the minimum temperature is negative; the lowest value found is — 1·65° C. (at Stat. 74, 75 metres). The low temperatures are not a sure indication of the effect of the winter cooling at the surface in this region, but may quite as well be ascribed to horizontal movements of the water layers (the Labrador Current). The water masses between 25 metres and the level of minimum temperature are far from being homohaline and do not show any sign of such mixing as the convection in winter should create. —

The author has calculated the difference of temperature between 200 and 400, 400 and 600 metres and so forth for intervals of 200 metres down to 1200 metres, for all stations available from the North Atlantic. The results may be summarized in the following way (numbers in brackets indicating the mean variation according to the definition given above):

The vertical variations of temperature are relatively small at all depths below 200 metres in the Arctic or Subarctic water in the northwestern area, S. of Greenland. In the Great Atlantic Current ("The Gulf Stream") the vertical variations may be very great. Apart from these regions we find, for depths *between 200 and 400 metres:* minima of temperature variation (0 to —0·5) in the sea off the Bay of Biscay and the British Isles, and in the ocean E., N. and W. of Bermuda; maxima (— 2 to — 3) near the equator, in the ocean N. and E. of the Antilles and also in some isolated areas S. of 25° N. For *400 to 600 metres* we have: a minimum (0 to — 0·5) in the eastern North Atlantic off north-western Morocco and northwards; a maximum (about — 2) N. and E. of the Antilles. For *600 to 800 metres* we have: a minimum from Morocco and Madeira northwards, sometimes with an inversion of temperature (the mean variation positive, maximum about + 0·2) due to water from the Mediterranean; another minimum is found near the equator; and a maximum (about — 2) in the sea around Bermuda. For *800 to 1000 metres* we have: a minimum in the eastern North Atlantic N. of Morocco and Madeira (sometimes with inversion) and in the sea S. of 18° N.; a maximum (about — 2) W. of Bermuda. For *1000 to 1200 metres* we have: a minimum in the tropics (0 to — 0·5) and in the easternmost part of the ocean as far north as about 43° N. (+ 0·3 to — 0·5); and a maximum (— 1 to — 1·5) near Bermuda.

Below 1200 metres the vertical gradient of temperature decreases with depth towards the stratosphere and is usually small except in those areas in the eastern part of the ocean where water from the Mediterranean exerts a considerable influence. The difference is easily seen by comparing, for instance, the curves for Stats. 17 and 25 B (pp. 65* and 66*) with the curves for Stats. 63, 65 and 66 (pp. 69* and 70*).

VII. THE SALINITIES IN THE NORTH ATLANTIC.

38. Horizontal and Vertical Distribution of Salinity.

The curves for the stations and the sections in Part II clearly demonstrate a correspondence between temperature and salinity as regards their vertical and horizontal distribution.

With the scales used for the construction of the station-curves on pp. 65*—72*, the curves representing the vertical distribution of temperature and salinity in the open sea at a sufficient distance from the coasts, are of nearly the same shape, at any rate when the upper part is not considered. As most of the stations are worked when the heating at the surface is well advanced, the difference is considerable in the surface layers, and this difference becomes more pronounced the later in the warm season the observations are made. In the upper strata the vertical variations in temperature in summer are great as compared with the variations in salinity. From, say, 50 or 100 metres downwards for several hundred metres the two curves usually run almost parallel to each other in nearly all the regions investigated during the "Michael Sars" Expedition. In the western North Atlantic the vertical gradient of salinity becomes numerically smaller, in relation to the vertical gradient of temperature, the deeper one goes. In our arrangement of the curves in the graphs this appears in their convergence (see, for instance, the curves for Stats. 65 and 68). It corresponds to the concave shape of the curve on p. 74* illustrating the normal correlation of the two elements, in which a certain variation of salinity corresponds to a greater variation of temperature when the temperatures are low than when they are high.

In those regions of the eastern North Atlantic which were investigated by the "Michael Sars" Expedition, water from the Mediterranean exerted a very varying influence. The appearance of this water creates an increase of salinity and a rise of temperature at intermediate depths, or makes the vertical gradients of salinity and temperature smaller on the upper side of the layers in question (and greater on the under side) than they would otherwise have been. Where the Mediterranean water is especially prominent — in the region outside the Straits of Gibraltar — the curves are of quite a different shape from those, say, for the western part of the North Atlantic. The conditions are clearly demonstrated by the curves for Stats. 17, 23 and 25 B.

Disregarding the irregularities caused by water from the Mediterranean, we may state that the salinity decreases from the surface (or a little below it) to the great depths practically everywhere in the Atlantic N. of the tropics except in areas influenced by coastal water or Arctic water.

Water from the South Atlantic with relatively low salinities advances northwards at intermediate depths as far as the northern tropic, with its core at 800—1000 metres below the surface. This is pointed out more especially by MERZ and WÜST. The conditions are clearly demonstrated by two sections constructed by WÜST [1928] and reproduced here in Figs. 32 and 33. The sections follow a curved irregular course, mostly along the deepest (central) parts of the western (Fig. 32) and the eastern (Fig. 33) North Atlantic. The effect of water from the Mediterranean is also distinctly seen in Fig. 33 (maximum at about 1000 metres between 30° and 40° N.).

In areas where the Atlantic water is covered by diluted water near the coasts or by Arctic water with its comparatively low salinities, the salinity naturally increases from the surface downwards until a maximum is found in the upper part of the Atlantic water. Where Atlantic and Arctic currents meet the conditions may, however, be rather complicated, with different kinds of water in succession vertically, as is demonstrated, for instance, by the curves for our Stats. 66, 80 and 82 and to the right in Fig. 32.

Variations in the temperature of a definite mass of water not mixed with other water, chiefly originate somewhere at the surface. Some heating is, however, also caused by absorption of heat radiation penetrating through the surface. Changes in salinity start exclusively at the very surface (evaporation, addition of fresh water) and the mean salinity cannot be altered except by phenomena occurring there. Variations of salinity within the water even close below the surface can only be induced by mixing processes. The molecular diffusion, like the mole-

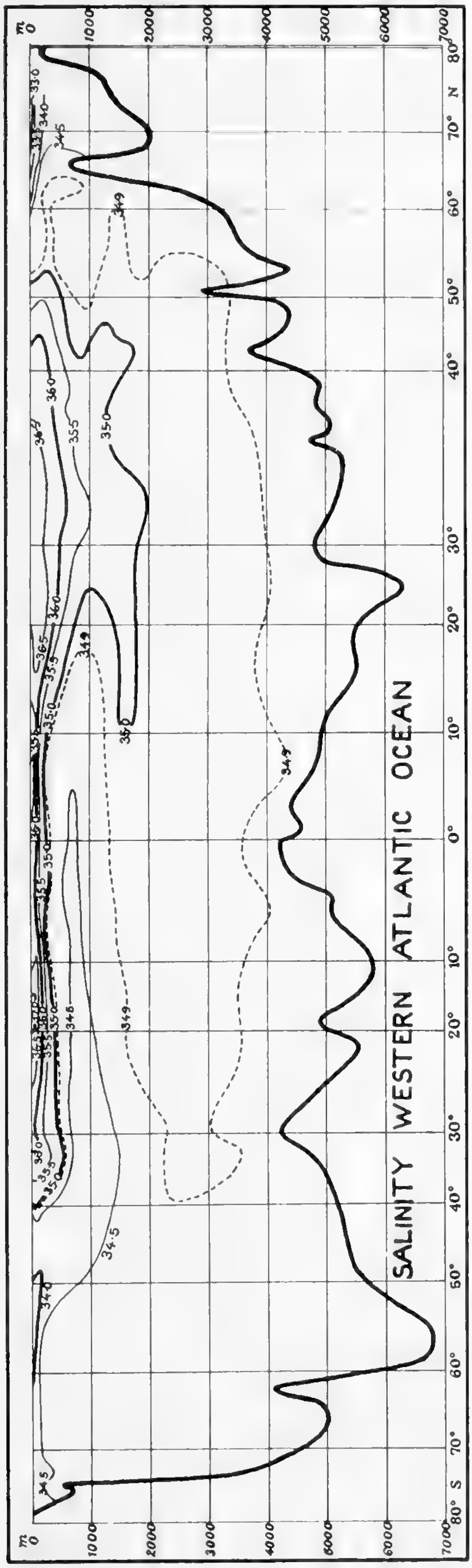


Fig. 32. Section along the deepest parts of the *western* Atlantic Ocean between 80° S. and 80° N., demonstrating the vertical distribution of salinity (according to G. WÜST).

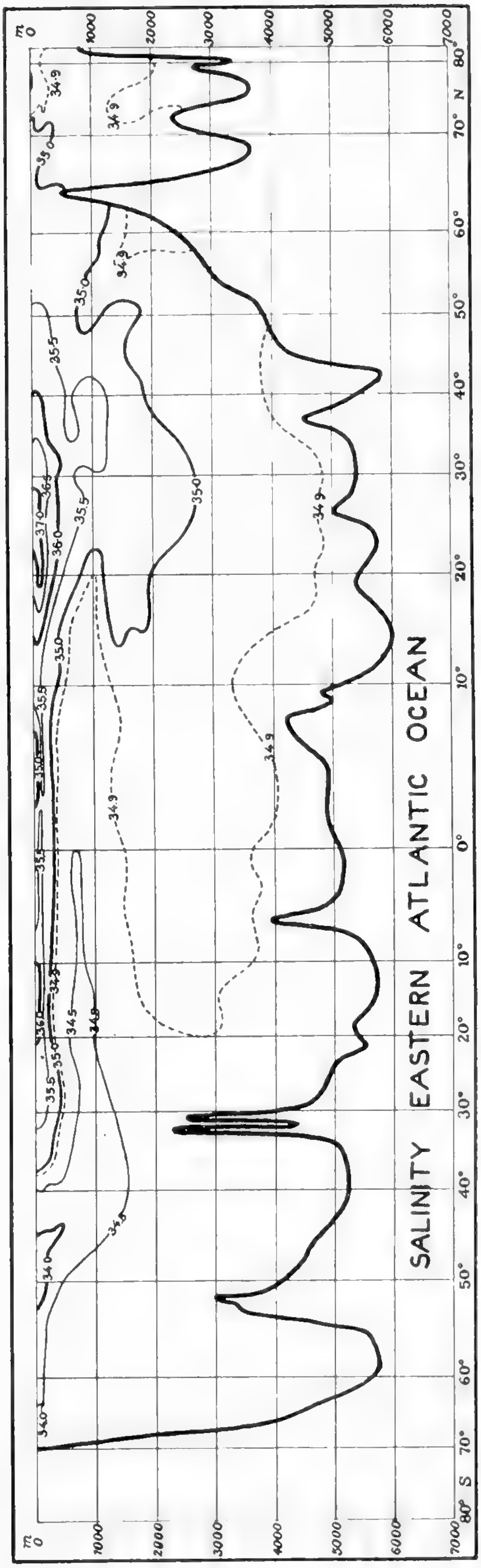


Fig. 33. Section from the *eastern* part of the Atlantic Ocean, corresponding to the section in Fig. 32.

cular conduction of heat, is negligible. But the turbulence has an effect upon the variations of salinity similar to that which it has upon the variations of temperature, and just as we speak of a virtual conductivity of temperature we may speak of a virtual diffusion of salt, which is generally very much greater than the molecular diffusion. Such variations of salinity *(S)* with time *(t)* that are solely due to the diffusivity in vertical direction may be expressed by an equation analogous to that available for temperature (p. 44):

$$\frac{\partial S}{\partial t} = \nu \frac{\partial^2 S}{\partial z^2} + \frac{\partial \nu}{\partial z} \frac{\partial S}{\partial z},$$

where ν is a "virtual coefficient of diffusion" which has precisely the same value as the virtual coefficient of temperature conductivity.

The evaporation and dilution of the surface waters are evidently subject to seasonal and annual variations due to climatic changes. We shall not, however, try to examine such variations here, but confine ourselves to a short survey of the average conditions.

Fig. 34 illustrates the average distribution of salinity at the surface of the Atlantic, according to Professor G. SCHOTT [1926]. The chart is rather schematic and does not show the many local differences to be found in places where strong currents or eddies occur.

In the region of the N.E. trade wind an excess evaporation takes place. The salinity increases all the way in the surface current from Portugal past Madeira and the Canary Islands, with the result that a maximum of salinity appears in the southern part of the Azoric high-pressure region. Within quite a large area W. and SW. of the Canaries the salinity at the surface exceeds 37 ‰, the absolute maximum being a little above 37·5 ‰. The salinities decrease S. of this area to a minimum with salinities below 35 ‰, appearing in a belt across the ocean in about 5° N. This belt almost corresponds to the region of maximum temperature at the surface (average for the year). Hence it follows that the positive correlation between temperature and salinity which usually appears in the ocean, does not exist in the case of the surface waters, between about 25° and 5° N. where, in fact, it is changed into a negative correlation.

The isotherms representing the mean annual temperature at the surface of the North Atlantic lie comparatively close together on the coast of the United States of America, where the isotherms for temperatures between 25° and 10° C. are crowded between 30° and 40° N. They spread, fan-like, over the sea. At 20° W. we find the isotherm for 25° C. at about 12° N., and that for 10° C. at about 58° N., a difference in latitude of 46°, as against 10° on the American coast. The isotherms do not form closed curves as some of the isohalines do. A comparison of the isotherms in question and the isohalines shows an agreement in some regions, while in others the two sets of lines run obliquely towards each other or even straight across each other.

In the northern regions except S. of Greenland the agreement is quite good: 35·5‰ corresponds to 13° C, 36‰ to 16½°, 36·5‰ to about 20°. There is no agreement between the 35·0-isohaline and the isotherms. The curve on p. 74* gives the following interdependence: 35·5‰ and 11° C., 36‰ and 15·20°, 36·5‰ and 18 1/4°, or lower temperatures in relation to the salinities than are given by the chart for the mean annual temperature, the difference being about 1½—2° for the regions in question. This difference is easily explained by the fact that our correlation curve (Fig. p. 74*) is based upon observations from the deeper strata, which chiefly represent a winter situation, so to say (cf. p. 52). In his "Geographie des Atlantischen Ozeans" SCHOTT has published charts of the mean surface temperatures in February, May, August and November. If we compare the isohalines (Fig. 34) with the isotherms in SCHOTT's chart for May in the same regions as above we find a good agreement with the data found from the correlation curve. The temperature chart for February shows lower values in relation to the salinities. Our curve of correlation (p. 74*) is based upon observations from the western as well as the eastern North Atlantic. It will be seen from the details shown in the figure on p. 75* that the observations from the western part tend to give a higher temperature at a certain salinity than the observations from the eastern part. This may be explained by assuming that the waters of the Great Atlantic Current are cooled on their way eastwards, while the salinity is not changed to the same extent. The observations made during the "Armauer Hansen" expeditions in the eastern North Atlantic only, have been used for the construction of a curve similar to that reproduced on p. 74* [HELLAND-HANSEN and NANSEN, 1926]. This curve gives a lower temperature at a certain salinity than the curve based upon the "Michael Sars" observations. Using the curve for the "Armauer Hansen" observations we find, that 35·0‰ corresponds to 5° C., 35·5‰ to 11°, 36·0‰ to 14·3°, and 36·5‰ to 16·8°. SCOTT's temperature chart for the surface in February compared with the salinity chart (Fig. 34) shows that 35·5‰ corresponds to about 10° C., but otherwise the correspondence with the 'normal' conditions in the water-masses of the eastern North Atlantic is as close as can be expected. There is even a correspondence between the isohalines for 35·0‰ and the isotherm for 5° C. in the sea near Iceland. This seems to agree well with our conception of the general circulation between low and high latitudes: the surface

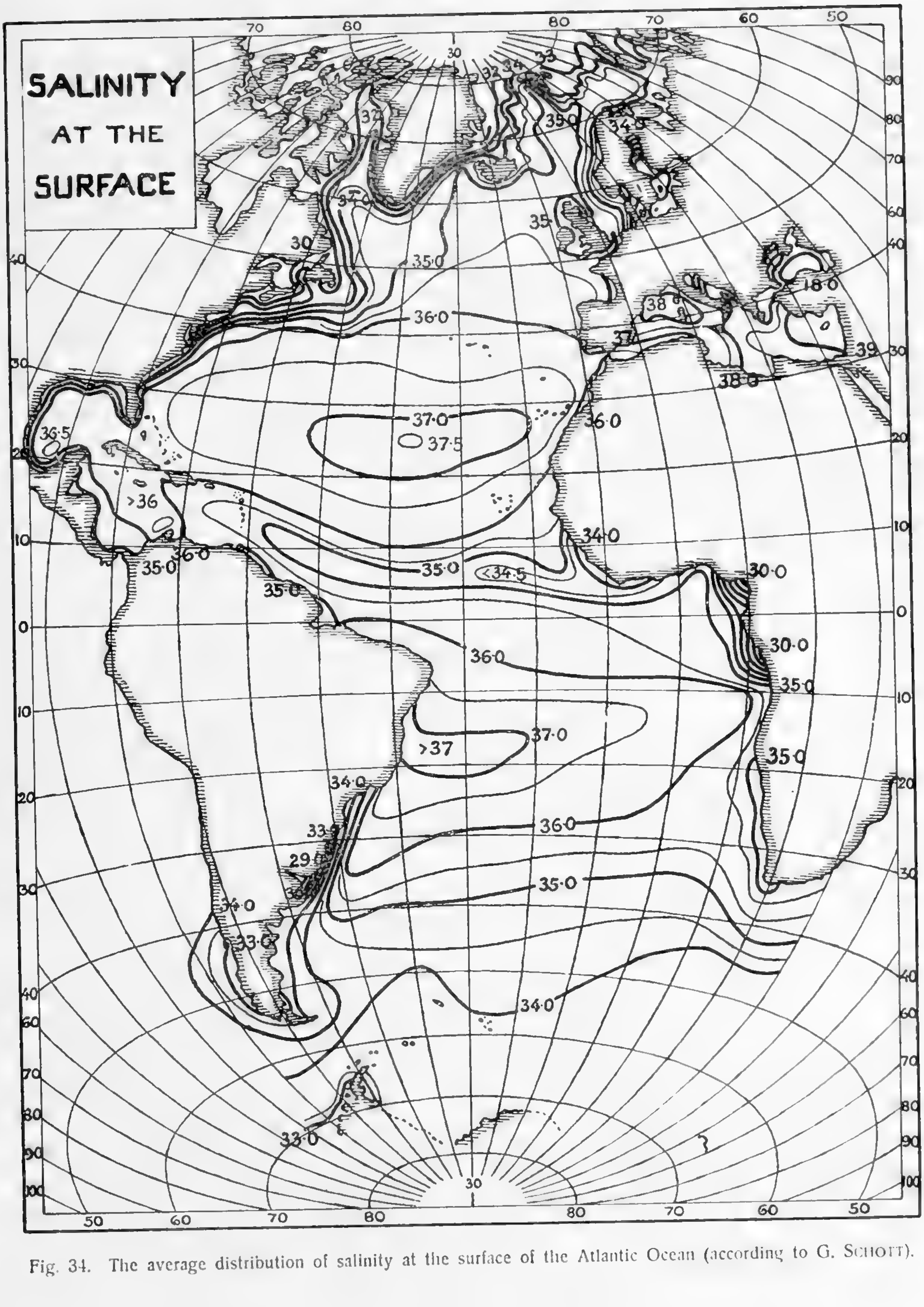


Fig. 34. The average distribution of salinity at the surface of the Atlantic Ocean (according to G. SCHOTT).

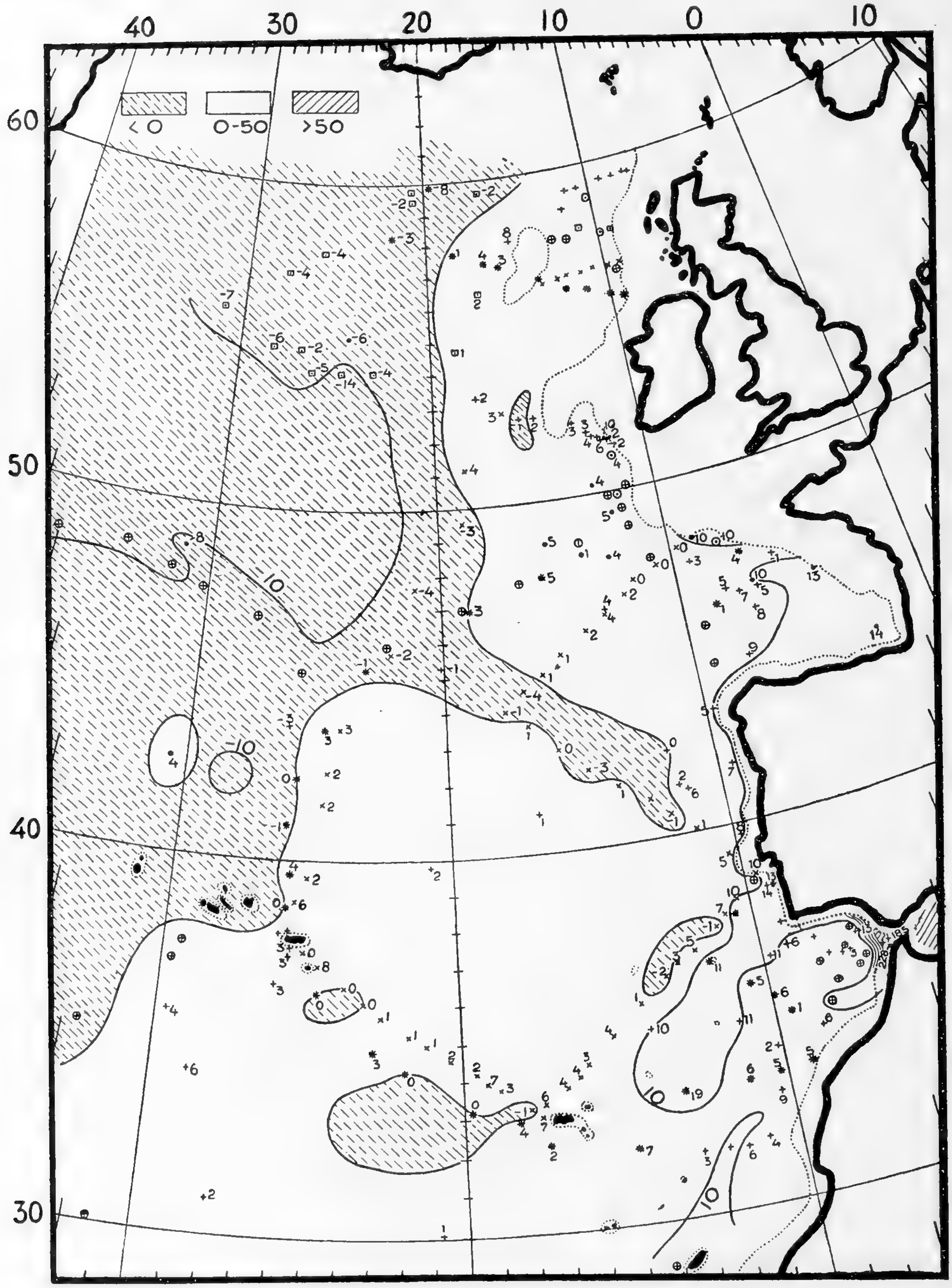


Fig. 35. The distribution of salinity-anomalies at 400 metres below the surface in the eastern North Atlantic.

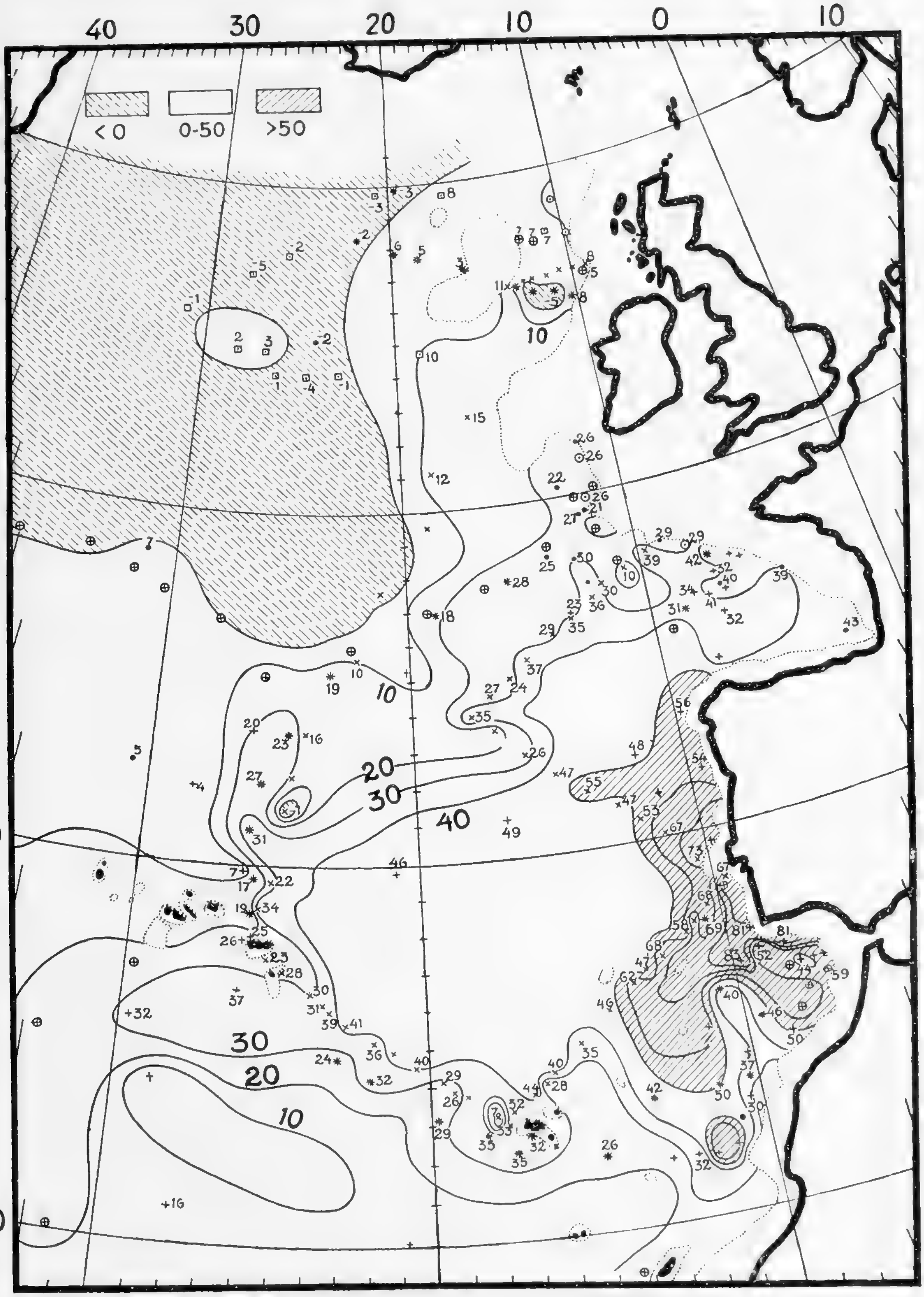


Fig. 36. The distribution of salinity-anomalies at 1000 metres below the surface in the eastern North Atlantic.

waters streaming from lower latitudes return as an underflow after having been cooled at higher latitudes, preferably in the cold season.

A difference of 1° C. in the North Atlantic corresponds, on an average, to a difference of 0·06‰ at 5°, 0·10‰ at 10° and 0·14‰ at 15° C. A variation in temperature from 10° to 15° C. corresponds to a variation in salinity of from 35·40 to 35·97‰, or a difference of less than 0·6‰. From the standpoint of biology the differences of temperature are evidently much more important than the differences of salinity in the open ocean where diluted coastal (or Polar) water does not occur. The vertical variations in salinity are generally quite small. In the central parts of the North Atlantic, where the salinity at the surface may be as high as 37‰ while it is 35‰ at about 2000 metres, the mean vertical variation per 100 metres is only — 0·1‰. A variation of — 0·5‰ per 100 metres would be extraordinary. In coastal and Arctic waters with increasing salinities downwards, the variations may be very considerable, as is well known. At Stat. 70 A, for instance, the difference in salinity between 37 and 46 metres was as much as 0·54‰.

On account of the agreement between temperatures and salinities and the law of parallel solenoids, some of the chief results mentioned in section 36 may be directly transferred and applied to the horizontal distribution of salinity. In particular it may be emphasized that great horizontal variations of salinity usually indicate a strong current (or great vertical differences of current velocity), and that salinity charts for different levels resemble each other when only the course of the isohalines is considered, and not the absolute values of salinity represented by them. The temperature charts on p. 96* may be almost directly 'translated' into salinity charts. Figs. 28 and 29 show the horizontal distribution of both temperature and salinity at 400 and 1000 metres' depth below the surface in the eastern North Atlantic, where the comparatively large number of observations have made it possible to give many details.

39. The Distribution of Salinity-Anomalies.

In the preceding sections we have repeatedly mentioned the agreement between salinities and temperatures. A deviation from the average conditions as regards the correlation between these two elements indicates that the water has either an abnormal temperature in relation to the salinity or an abnormal salinity in relation to the temperature. In section 32 we have started from the salinity as an independent variable quantity and used the anomalies of temperature for examining the seasonal variations of temperature in the upper water-strata. We shall now briefly examine the salinity-anomalies, starting from the temperature as an independent variable (section 18). This may preferably be done in the case of depths below 200 metres where the seasonal variations of temperature are comparatively small. It is self-evident that a negative anomaly of temperature corresponds to a positive anomaly of salinity, and *vice versa.*

On p. 97* we reproduce some schematic charts illustrating the distribution of salinity-anomalies at 100, 400, 1 000 and 2 000 metres below the surface in the North Atlantic Ocean. The chart for *100 metres* cannot give a true picture of the distribution, because the seasonal variations of temperature are considerable at this depth. In spite of the uncertainty it seems, however, to be an established fact that *the salinities at 100 metres are relatively high as compared with the temperatures in the north-east trade region, and relatively low in the north-western part of the Atlantic.* The high positive salinity-anomalies in the former region should probably be attributed to cooling, caused by the northerly winds prevailing there. The low salinity-anomalies in the north-western part of the ocean at 100 metres' depth show the influence of Arctic (or Polar) water of low salinities. The curves representing the distribution of salinity-anomalies at 100 metres in the region S. and E. of New Foundland show almost the same shape as the isotherms reproduced in the charts on p. 96*. The curves lie very close together in a belt corresponding to the site of the Great Atlantic Current. If we have 'Gulf Stream' water with a salinity of 36·3‰ and a temperature of 17° C. mixed with equal quantities of Polar water with a salinity of 33‰ and a temperature of — 1°, we obtain water of 34·65‰ and 8° C. At the latter temperature the salinity should normally be about 35·2‰ in the North Atlantic, according to our curve on p. 74*. Hence the salinity-anomaly of the mixed water should be about — 55. If more Polar water is mixed with the Atlantic water, the negative anomalies of salinity become greater. A mixture of one part of Atlantic water with two parts of Polar water, both constituents having the salinities and temperatures mentioned above, would give a salinity-anomaly of about — 90. The chart for 100 metres on p. 97* seems to show that the negative values of the salinity-anomalies are greatest just in the regions where the Polar water comes nearest to the Great Atlantic Current.

The chart for *400 metres* on p. 97* shows *very small variations in the horizontal distribution of salinity-anomalies in spite of the fact that the horizontal variations of temperature are very great* (cf. the chart on p. 96*).

At *1 000 metres* very high positive values of salinity-anomalies appear from Southern Europe and north-western

Morocco westwards towards the Sargasso Sea and northwards towards the Bay of Biscay and still farther north. This is due to *the propagation of water from the Mediterranean.* The salinity-anomalies reach a maximum off Southern Portugal, which indicates that the water from the Mediterranean at this depth chiefly moves along the south-western coast of Spain and Portugal, probably as an effect of the rotation of the earth. The high values of the salinity-anomalies in these regions are not due to variations in the vertical distribution of the water-masses, as a similar distribution is also found at 800 and 1200 metres.

At *2000 metres* we also find comparatively high positive values of salinity-anomalies in a region extending from Southern Spain and Portugal to the west and north. *Relatively salt water appears at this depth off Southern Europe and in the Bay of Biscay, and in the sea around Madeira and south and south-west of the Azores.*

The small-scale charts on p. 97* are rather schematic. Figs. 35 and 36 show the distribution of salinity-anomalies in more detail at 400 and 1000 metres in the eastern part of the North Atlantic. These charts correspond to the charts of temperature and salinity reproduced in Figs. 28 and 29.

Some sections are reproduced on pp. 87*, 89* and 93*, illustrating the vertical distribution of salinity-anomalies. A comparison of these sections with the corresponding sections showing the distribution of temperature and salinity gives an impression of the advantages afforded by the method of salinity-anomalies. By this method the admixture with the Atlantic water of Mediterranean water on the one hand, and of Polar water on the other, seems to come out more clearly than by the usual study of the distribution of isotherms and isohalines alone.

VIII. STABILITY.

40. Calculation of the Stability.

We have mentioned above (section 34) that a perfect mixture of water-masses creates a uniform salinity while the temperature rises slightly downwards owing to the adiabatic effect. In these circumstances we have a state of neutral equilibrium and the stability is $= 0$. The potential density is then the same everywhere. In by far most cases the water-masses are not thoroughly mixed, the salinity showing vertical variations and the temperature a vertical gradient different from the adiabatic, with the potential densities increasing downwards. The greater the increase of the potential densities in vertical direction, the greater is the stability. In hydrographical tables the values of σ_t are, as a rule, published, and we may obtain an approximate value of the stability simply by computing the vertical variation per metre of σ_t. In so doing we neglect the adiabatic influence. In the deep water, for instance, we may find a decrease of σ_t downwards and, seemingly, a state of instability, while neutral equilibrium or even a state of positive stability is found when the adiabatic variations of temperature are taken into account. In such cases a more exact calculation of the stability is needed.

Hesselberg and Sverdrup [1915] have published tables for the computation of the stability, E. They have expressed the stability in the following way:

$$E = \frac{\varrho - \varrho'}{\triangle z}$$

where ϱ means the density of the water at the depth z and ϱ' the density of a water particle which has been moved to the same depth from a depth $z + \triangle z$. In a series of tables Hesselberg and Sverdrup have given values for the effects of variations in salinity, temperature and depth upon the stability, so the final value of E can be found by addition. The observations from the "Michael Sars" Expedition have been manipulated by means of these tables, and the results are given in the 5th column of Table III in Part II. In a later publication [1929] Hesselberg has shown that the values found in this way are not quite exact, but the errors are of no consequence in the present connection.

As mentioned on p. 21, $10^8 E = 1000$ corresponds nearly to a vertical variation of 0·01 of σ_t per metre.

41. Horizontal and Vertical Variations of Stability.

The stability varies in the upper water-strata in the course of the year on account of variations in heating and cooling. The cooling at the surface in winter tends to create a state of instability, and sometimes the water at the very surface may be a little heavier than the water below until the vertical convection brings about a thorough mixing. Such instability may also be observed as the result of cooling during the night or an increase of the surface salinity on account of evaporation. Examples of

negative values of E are found at Stats. 4, 16, 25 B, 26, 30, 35, 50, 53, 69 and 92, where the instability is due to an increase of the salinity at the surface. At Stats. 6, 29, 31 and 83 the negative values of E between the surface and 10 metres are due to a comparatively low temperature at the surface. At Stats. 34, 44 and 46 the temperature is lower and the salinity higher at the surface than at 10 metres. Some of the stations where the temperature at the surface is lower than at 10 metres were worked during the night, while in some cases when the stations were worked in the day-time the temperature of the air was relatively low, which probably indicated cooling of the surface water. Negative values of E are only rarely met with at greater depths than 25 metres below the surface. Nowhere at these depths is the negative value of E greater than may be accounted for by errors of observations, especially as regards the salinity. In each of these cases an error of 0·01‰ in the determination of salinity may explain why the value of E has been recorded as negative.

We can obtain a clear picture of the seasonal variations of stability in the upper water-layers by comparing the stations in the eastern part of the North Atlantic off the Bay of Biscay worked in April (for instance Stats. 4—9), with those worked in July (Stats. 90—93). In the open ocean the stability is practically always low in the upper 10 metres on account of the mixing caused by wind. At greater depths, and especially between 25 and 50 metres, the stability is very high in summer, indicating a quasi-discontinuity. The upper boundary of the discontinuity-layer may be regarded as the lower boundary for the effective mixing by wave-motion.

There is an intimate correspondence between the vertical variations of stability and the value of the virtual coefficient of temperature conductivity and diffusion. Low values of E mean comparatively high values of ν and *vice versa*.

As has been mentioned before, the vertical variations of salinity have generally less effect upon density than the vertical variations of temperature. The vertical and horizontal variations of stability, therefore, show a marked coincidence with the variations of temperature, and the stability exhibits seasonal variations parallel to those of temperature. In our examination of the distribution of stability, therefore, we must consider the season when the observations are made, when dealing with, say, the upper 200 metres.

The horizontal variations of stability are intimately connected with the local variations of the currents, as they are with the distribution of temperature. On account of the local variations in velocity and vertical extension of the currents the horizontal distribution of stability is rather irregular, as will be seen from the charts on p. 98*.

The chart for *75—100* metres shows great variations. These are largely due to seasonal variations, a fact especially apparent in the area south of Ireland. Some high values of the stability in the vicinity of the Straits of Gibraltar are due to the transition from the relatively light Atlantic water above to the heavy water from the Mediterranean below. The very pronounced stability at some places in the western part of the North Atlantic is connected with the appearance of the Great Atlantic Current or the great vertical variations below the arctic water near New Foundland.

Between 150 and 200 and between *300 and 400 metres* the stability is as a rule considerably less than between 75 and 100 metres. *Between 500 and 600 metres* and between *700 and 800 metres* the stability becomes, to some extent, greater again, because the lower limits of the great currents are, in many places, met with at these depths. *At 900 and 1000 metres and deeper down* the values of the stability are as a rule comparatively low, decreasing with the depth until the stability approaches nought in the deep water.

IX. DYNAMICS OF THE SEA.

42. Theoretical Considerations.

It is a well-known fact that the tangential stress of the wind along the sea surface causes a displacement of the surface water, and that a prevailing wind of appreciable strength may give rise to ocean currents of even great extension. It is also an established fact that differences in the horizontal distribution of temperature and salinity in the sea cause a disturbance of the hydrostatic equilibrium and provoke convection currents. The actual ocean currents are the combined effect of wind and differences of density. We shall not here discuss the special kinds of currents caused by the tides.

In a series of important papers Professor WALFRID EKMAN has discussed the problem of the *wind currents.* The chief results of his investigations are that the wind in open sea will create a current at the surface which is deflected about 45° *cum sole* from the direction of the

wind. Owing to the friction the water-masses below the surface are also moved but with decreasing velocities and more and more *cum sole* as one goes downwards from the surface. At a depth called the depth of frictional influence the direction of the pure wind-current is exactly contrary to the direction of the current at the surface, but at this depth the velocity is reduced to a small fraction only — say 4 % — of the surface velocity. The average flow of the water in a pure wind-current goes at a right angle *cum sole* from the direction of the wind. The surface layers will thus be driven to the right of the wind in the northern and to the left in the southern hemisphere. A sloping of the surface is thus established. In homogenous water the pressure will increase at all levels from the surface to the bottom in the regions where an accumulation takes place. The excess pressure creates a gradient current extending from the surface nearly to the bottom. After a short while the gradient current will move more or less in the direction of the wind. In the stratified water of the ocean, the surface layers will be pressed down on the right hand side of the wind in the northern hemisphere, so the isopycnal, isothermal and isohaline surfaces will assume a slanting direction, deepest to the right and highest to the left (and *vice versa* in the southern hemisphere). In this case an interior field of force is established in the sea. Such a field of force in stratified water will be called a solenoidal field, in accordance with the terminology of Professor V. Bjerknes.

Even if there were no winds a system of ocean currents would be created on account of regional differences of density. As an example it will suffice to mention the differences of density between low and high latitudes. In low latitudes the water is heated so much that it becomes lighter than the water in higher latitudes even if the salinity is increased by evaporation. The light water has a tendency to spread over the heavier water. When the water-masses move, the rotation of the earth acts in such a way that the motion does not go in the direction of the force but at right angles to it, to the right in the northern and to the left in the southern hemisphere (*cum sole*).[1])

The actual solenoidal field may be the composite result of solenoidal fields created indirectly by the wind and more directly by thermal influences, evaporation etc.

The 'Coriolean force' with which the *rotation of the earth* acts upon unit mass ('the accelerating force') is expressed by the well-known equation:

$$R = 2\,\omega\,v\,sin\,\varphi, \qquad (a)$$

[1]) The conditions in the sea are analogous to those in the atmosphere, where the wind does not blow in the direction of the pressure gradient but nearly along the isobars.

where ω is the angular velocity of the earth (0·0000729), v the velocity of the mass particle and φ the geographic latitude. *Under stationary conditions this force is directed contrary to the resultant of the real physical (moving) forces and has the same value.* The movement takes place at a right angle *cum sole* from the physical forces and *contra solem* from the Coriolean force.

Apart from the wind stress at the surface, the physical forces in the ocean are those of gravity, pressure and friction. The acceleration of *gravity, g,* varies slightly with the latitude and with the depth below the surface, g increasing with latitude as well as with depth, apart from some insignificant local irregularities. The free surface of a liquid which is motionless relatively to the earth, is perpendicular to the direction of gravity (the plumb-line) and forms a *level surface.* No work will be required to move a weight along such a surface if gravity is the only acting force. In other words, a level surface is a surface of constant gravity potential (an equipotential surface). If, as an effect of atmospheric conditions or for other reasons, the sea surface is inclined at an angle γ from the level surface, the gravitational force will have a component along the sea surface, this component being $g.\,sin\,\gamma$ per mass unit. The angle will always be so small that we can simply write $g\gamma$. Any number of equipotential surfaces may be constructed, each of them characterized by being perpendicular to the plumb-line. When a mass m is lowered from such a surface to the next one, the gravitational force performs a work, w, which is equal to $m.g.h$, h being the vertical distance between the two surfaces. One may represent the gravitational field by constructing a series of surfaces at a distance from one another which corresponds to unit increase of gravitational work per mass unit ($g.h = 1$). The distance between two such level surfaces will then be $h = \frac{1}{g}$. As g is nearly 10, the distance between two succeeding level surfaces will be about 0·1 metre in the metre-ton-second system of units. This distance has been called by V. Bjerknes a dynamic decimetre, and a distance ten times as great a *dynamic metre.* Since g varies with latitude and depth, the dynamic metre is not a constant length like the ordinary metre. At sea-level the dynamic metre is 1·02246 ordinary metres at the equator and 1·01716 metres at the pole. The length of the dynamic metre decreases slightly with the depth below sea-level because g increases downwards in the ocean. A dynamic metre will always, however, be nearly 102 cm. Inversely we have 1 metre $= \frac{g}{10}$ or about 0·98 dyn. m. The dynamic metres are always used to measure *vertical* distances only. If ΔD

is the distance in dyn.metres between two points in the sea and h the vertical distance in metres we have

$$\triangle D = \frac{g. h}{10},$$

where g is an average value of g in the space between the two points.

If we have two points A and B (Fig. 37), with a vertical difference of h metres (or $\triangle D$ dynamic metres) and a distance l metres between them, and the angle

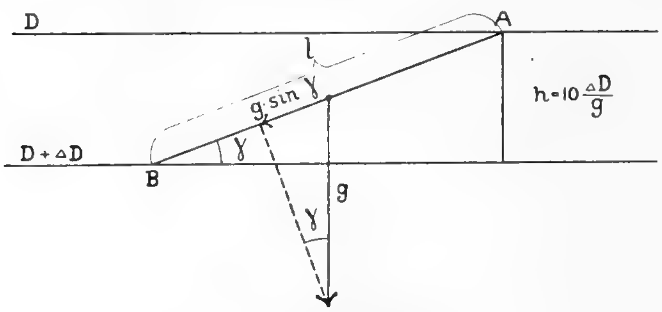


Fig. 37. The gravitational force.

between the line $A B$ and the level surfaces D and $D + \triangle D$ through A and B is γ, the gravitational work done in moving a unit mass from A to B is:

$$W = l. \bar{g}. \sin \gamma = l. \bar{g}. \frac{h}{l} = g. h = 10 \triangle D.$$

The acting force per unit mass in the direction from A to B is

$$G = \frac{W}{l} = \frac{10 \triangle D}{l} \tag{b}$$

The hydrostatic *pressure*, p, is generally defined as a force per unit area, *i. e.* per square metre in the m.t.s. system. It has become customary in oceanography to neglect the atmospheric pressure when dealing with the pressure within the sea. The pressure at a depth of h metres is then simply equal to the weight of the vertical water column from the surface to h metres, covering a horizontal area of 1 square metre. If the average density (compression included) is $\bar{\varrho}$, the average weight per cubic metre is $\overline{\varrho. g}$, and the pressure

$$p = \bar{\varrho}. \bar{g}. h = \bar{\varrho}. 10\, D \text{ m. t. s. units},$$

D being the depth in dynamic metres. When we introduce specific volume (α) instead of density we get:

$$D = \frac{1}{10} \bar{\alpha}\, p.$$

A pressure of 10^6 dyne/cm^2 has been called a *bar*, which almost corresponds to an atmosphere. The m.t.s. unit of pressure is 1/100 bar, or a centibar. V. BJERKNES has introduced the *decibar* = 1/10 bar as a *technical* unit of sea pressure. This corresponds to the pressure exerted by a water column which is nearly 1 metre high. The relation between dynamic depth and pressure is expressed by one of the equations

$$p' = \bar{\varrho}. D \text{ decibars}$$

$$D = \bar{\alpha}. p' \text{ dynamic metres}$$

When we know the vertical distribution of density or specific volume in the sea, we can easily find the pressure at a given dynamic depth or the dynamic depth corresponding to a given pressure. The compression of the water must be considered in the calculations.

On account of variations in density the isobaric surfaces will not, as a rule, be parallel to the level surfaces, but intersect them. In a level surface there will usually be variations of pressure, and in an isobaric surface variations of dynamic depth. We can draw isobars in a chart for a certain dynamic depth, which is similar to the isobaric charts used in meteorology. Or we can draw isobaths for equal dynamic depth in a chart for a certain isobaric surface, which is similar to topographical charts. In a surface of equal depth (in ordinary metres) below the surface of the sea there will, as a rule, be variations both of pressure and of gravity potential (dynamic depth). A dynamic chart for such a surface would therefore contain two sets of lines, isobars and isobaths, while in the isobaric charts or the topographical charts just mentioned, we have only one set of lines. The latter charts are therefore much simpler and more convenient for a discussion of the dynamics of the sea.

Along a level surface the force due to differences in gravity potential is 0. If occasionally the difference of pressure is likewise 0, the water is subjected to no moving force at all. But generally the pressure varies along the level surface, with the result that a force will act in the direction from a place with a higher pressure to a place with a lower pressure. Let us suppose that we have a station with the pressure p_1 decibars at a dynamic depth D and another station, l metres away, with the pressure p_2 at the same level $(p_1 > p_2)$, and imagine that we have a straight tube with a cross section of one square metre laid between the two points. The tube will have a volume of l m^3 and contain a mass of water $m = \bar{q}. l$, when q is the average density within the tube. This mass will be moved by a force $= p_1 - p_2$ technical units or $10\, (p_1 - p_2)$ m.t.s. units in the direction from the first station to the second and acquire an acceleration a. Leaving friction out of account we have

$10\,(p_1 - p_2) = m.a = \bar{q}.l.a.$ The force per unit mass (which is equal to the acceleration), is then:

$$P = 10\,\frac{p_1 - p_2}{\bar{q}.\,l} = 10\,\frac{\bar{\varrho}_1 - \bar{\varrho}_2}{\bar{q}.\,l}.D \qquad (c)$$

It can be shown that the force of *friction* per unit mass is:

$$F = \alpha\left(\mu\,\frac{\partial^2 v}{\partial z^2} + \frac{\partial \mu}{\partial z}\,\frac{\partial v}{\partial z}\right) \qquad (d)$$

α being the specific volume and μ the virtual coefficent of viscosity. The friction usually acts against the current but in a very different degree according to the variations in μ and the vertical variations of velocity. The conditions depend greatly upon the turbulence. At present it is difficult to take the frictional force into account in numerical calculations. In an exact treatment it should be combined with the other physical forces into a resultant force. We have reason to believe, however, that the friction is of small importance in comparison with the other forces; so in most cases it may be left out of account, and we shall neglect the friction in our discussion here.

Along a *level surface* the only force to be regarded is, then, the force due to differences in pressure. Under stationary conditions this force must have the same value as the Coriolean force. From equations (a) and (c) we obtain:

$$v'_D = \frac{p_1 - p_2}{2\,\omega.\,\bar{q}.\,L.\,sin\,\bar{\varphi}} = \varkappa\,\frac{p_1 - p_2}{\bar{q}.\,L}\ \text{cm./sec.} \qquad (e)$$

where v'_D is the average component of velocity relatively to the surface water (see below), the component being reckoned at a right angle to the line between the stations 1 and 2 at the level surface at the dynamic depth D. p_1 and p_2 denote the pressure at the level surface at the two stations, L the distance between the stations in kilometres and $\bar{\varphi}$ the mean latitude. $\bar{q}$ is the mean density (compression included) along the level surface between the two stations, as mentioned above.

In a similar manner we find, by means of equations (a) and (b), the following expression for the component of the relative velocity normal to the line between the stations 1 and 2 in an *isobaric surface* where the pressure is $= p$:

$$v'_p = -\,\frac{D_1 - D_2}{2\,\omega.\,L.\,sin\,\bar{\varphi}} = -\,\varkappa\,\frac{D_1 - D_2}{L}\ \text{cm./sec.} \qquad (f)$$

We have assumed that the pressure at the level D is greater at Stat. 1 than at Stat. 2. The force due to pressure is, therefore, directed from 1 to 2. The distance in dynamic metres from the surface of the sea to the isobaric surface representing a pressure $= p_1$ is greater at Stat. 2 than at Stat. 1, *i. e.* $D_1 < D_2$. The force of gravity is directed from the smaller to the greater dynamic depth, which here means from Stat. 1 to Stat. 2 at the depths in question. With $(D_1 - D_2)$ in the numerator, therefore, we must put a minus before the whole expression in equation (f).

v'_D and v'_p are components of the velocities — relative to the surface water — in a direction at a right angle *cum sole* to the line from Stat. 1 to Stat. 2. They tell us nothing regarding the real components of the currents but only that they differ, by the amounts v'_D and v'_p in the direction mentioned, from the velocity component at the sea surface. If the component of the actual current is 0 at the level surface for D dynamic metres the actual current at the surface of the sea has a component $= -\,v'_D$, *i. e.* 90° *cum sole* from the direction from Stat. 2 to Stat. 1. In general we have:

$$-\,v'_D = c_0 - c_D,$$
$$\text{and}\quad -\,v'_p = c_0 - c_p,$$

where the real components of the actual currents are c_0 at the surface of the sea, c_D at the level surface for D dynamic metres and c_p at the isobaric surface for p decibars, the components being taken in a direction 90° *cum sole* from the direction from Stat. 2 to Stat. 1. The pure wind-current in the uppermost water-layers is then disregarded.

The results arrived at here in an elementary fashion agree perfectly with those which may be found by starting from the well-known circulation theorem formulated by Professor V. BJERKNES [1898, 1901]. The equation developed by BJERKNES makes it possible to calculate the acceleration of circulation when the distribution of mass and velocity in the ocean is known. SANDSTRØM and the author [1902] transformed BJERKNES's equation into a shape which was more convenient for such a calculation. The next step was taken by the author on the supposition that the accelerations of circulation in the sea may be neglected. Practically no error is introduced by taking the acceleration of circulation as equal to nil. Thus a formula was arrived at which is identical with our formula (f) above [HELLAND-HANSEN, 1905; cf. KRÜMMEL, 1911, p. 502].

The formulae developed above do not *a priori* assert anything about the causality. They only show the connection between a solenoidal field and the velocities of the current. Such a field may not only be the *cause* of a current but also the *effect* of it. As to the latter, we have an example in the effect of the winds mentioned above. We may also, as an example, consider the conditions in the Baltic current. The excess of water from

the Baltic is carried away through Oeresund and The Danish Belts which are comparatively very narrow and shallow. The out-flowing water proceeds along the southern coasts of Sweden and Norway. Owing to the influence of the rotation of the earth the surface layers are pressed to the right so that a solenoidal field is created.

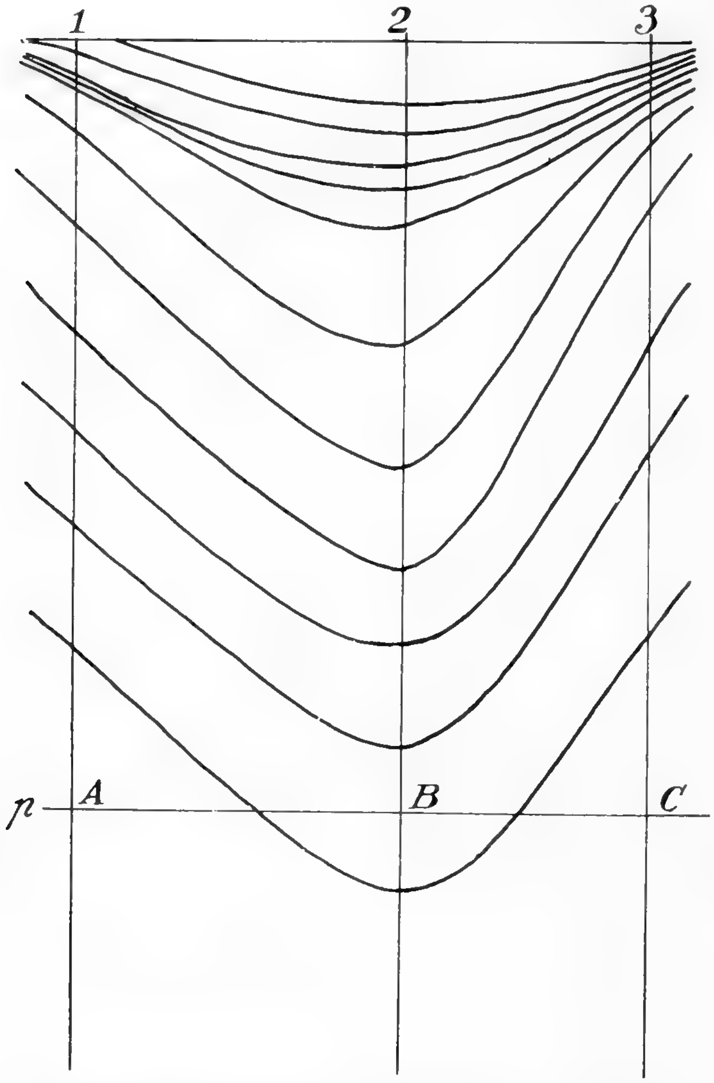


Fig. 38. An example of vertical distribution of σ_t. The water is comparatively heavy at Stats. 1 and 3 and light at Stat. 2.

Fig. 38 illustrates the conditions in a section through 3 stations, numbered 1, 2 and 3. The section may, for instance, have a direction N. — S. (cf. *e. g.* the lower section on p. 91*, Stats. 69, 67 and 66). The curved lines represent the distribution of density (σ_t). The water is comparativily heavy at Stats. 1 and 3, and light at Stat. 2. The line p represents a certain isobar. The distance in dynamic metres from the surface to this isobar is greater at B than at A and C. On the assumption that the velocities decrease from the surface downwards, as is usually the case, the current must, according to the theory set forth above, run with a component eastwards between Stats. 1 and 2 and westwards between 2 and 3. This means that the current runs in such a direction that the heavy water is found to the left and the light water to the right in the northern hemisphere (reversed in the southern hemisphere). If occasionally the velocity of the current increases with depth the light water will be found on the left-hand side of the current and the heavy water on the right-hand side in the northern hemisphere.

We may also draw another conclusion which is rather important. The isopycnals usually run almost parallel to the isotherms and isohalines. The isopycnals in Fig. 38 may, therefore, be considered as nearly equivalent to isotherms or isohalines. At first sight it might seem that the whole wedge-shaped body of water between stations 1 and 3 forms a characteristic current not only as regards its physical properties, but also in having practically the same direction of flow. According to what has been said above the flow is, however, in opposite directions at the two sides of the axis of minimum density (at Stat. 2). This axis is a critical one as regards the direction of flow. Quite analogous conclusions hold good, of course, when we have a section with an axis of maximum density.

In the next section we shall deal with the method of making numerical calculations, and discuss some of the results as regards the North Atlantic. We will only mention here some questions in connection with a study of the topography of isobaric surfaces. Having found the dynamic depth from the sea surface to a certain isobaric surface by means of observations of temperature and salinity at a number of stations, we can draw dynamic isobaths. The number of isobaths usually increase with increasing pressure (depth). When the friction can be neglected these isobaths will represent stream-lines for the currents along the isobaric surface relatively to the surface of the sea. Thus the conditions in the upper water-strata influence the construction of the charts even for great depths, which means that, for instance, the seasonal variations in temperature have to be considered. But we may also start from an isobaric surface at a particular depth and make our calculations upwards to the surface as well as downwards to greater depths. If the velocities of the currents in one of the isobaric surfaces are so small that they may be neglected, it is convenient to start from this surface. The topographical charts for isobaric surfaces higher up in the water will then directly show stream-lines for the actual currents, and the actual velocity will be inversily proportional to the distance between the isobaths. In this case the sea-

sonal variations in the upper water-strata have no influence upon the charts for other strata, and variations in the times when the different stations have been worked hardly affect depths below 200 metres. Thus topographical charts when rightly constructed may serve as current charts.

It was mentioned above (p. 79) that Professor WALFRID EKMAN has discovered a general law according to which the direction of a gradient current depends upon variations in the depth to the sea-bottom. In order to see whether this law finds expression in charts of dynamic topography Professor EKMAN and the author in 1922 studied some such charts from the North Atlantic. We were immediately struck by the almost complete agreement between the series of dynamic isobaths drawn for different isobaric surfaces. There is nothing remarkable in the fact that a current connected with a solenoidal field runs at all levels approximately in one main direction. This is only what one would expect as a normal state of things. But the agreement was in this case so close that the question naturally arose as to whether it depended upon some universal mechanical law. We believed that this question could be answered in the affirmative as far as stationary hydrographic conditions were concerned. Our reasons were as follows: Stationary hydrographic conditions imply that the isohaline and isothermal surfaces, and therefore the isosteric surfaces as well, *i. e.* surfaces combining all points with constant value of specific volume, retain their positions unaltered. Consequently any motion of the water across these surfaces is excluded, if allowance is made for the quite insignificant alterations of salinity and temperature which an individual bulk of water may undergo owing to diffusion and conduction of heat. Let us suppose that the isosteric surfaces slope — which they must in the case of gradient currents — and that the current itself is horizontal. Then the motion of the water, if it is not to cross the stationary isosteric surfaces, must necessarily follow the horizontal tangents of the latter. On the other hand, according to a well-known dynamical law and leaving viscosity out of account, the relative velocity of a water-layer immediately below is directed along the same horizontal tangent, *i. e.* in the same direction or in an exactly contrary direction. From this it follows that the gradient current at all levels runs in one direction or in two exactly opposite directions only. From another point of view the same thing may be expressed by saying that all isosteric surface elements (and all isothermal and isohaline surface elements) along one vertical line must slope in the same, or in two exactly opposite directions.[1])

[1]) A more detailed proof of this theorem is found in a publication by V. W. EKMAN [1923].

The reader will have observed already that the validity of this *"theorem of the parallel fields of solenoids"* depends upon several assumptions besides the obviously necessary assumption of a stationary hydrographical condition. One of these assumptions is implied in the use of the ordinary dynamical connection between pressure gradient and velocity, for this is only possible, as EKMAN has shown [1923], when the horizontal dimensions of the region considered are not very small and when the stream-lines of the current are not very sharply bent as they would be, for instance, off a promontory. Other important assumptions are the disregard of viscosity and of any inclination of the stream-lines in comparison with the inclination of the isosteric surfaces. The necessity of all these assumptions involves us in some uncertainty as to the validity of the theorem. Nevertheless the undoubted theoretical reasons in its favour, in connection with the remarkable way in which it is applicable to the Great Atlantic Current and other cases, are a sufficient motive for retaining it as a working hypothesis and for trying to have it tested by observations.

43. Numerical Calculations.

The first object of the dynamical calculations is to find the pressure at different level surfaces or the dynamic depth from the sea surface to different isobaric surfaces. The basic observations of temperature and salinity at the stations are made at different depths in ordinary metres. A depth of 1000 ordinary metres corresponds to about 980 dynamic metres and a pressure of about 1010 decibars. For dynamic depths it is convenient to use standard numbers in dynamic metres and for pressures standard numbers in decibars similar to those used for the ordinary depths for which the records of temperature and salinity are given (standard depths, cf. section 16). The values of temperature and salinity at, for instance, 1000 dynamic metres are a little different from the values observed at 1000 common metres. The real values at the standard dynamic depths and the standard pressures could, of course, be found from the observations by interpolation, but the differences are so small that such an interpolation is unnecessary for practical purposes, and an observation from a certain standard depth, measured in ordinary metres, may be used without alteration as applicable to a depth of just as many dynamic metres or decibars.

In Table III the argument a means either ordinary metres, or dynamic metres, or decibars. The values of temperature, salinity and density without compression (columns 2—4) are given for the standard depths in ordinary metres, but they are also used directly, without any cor-

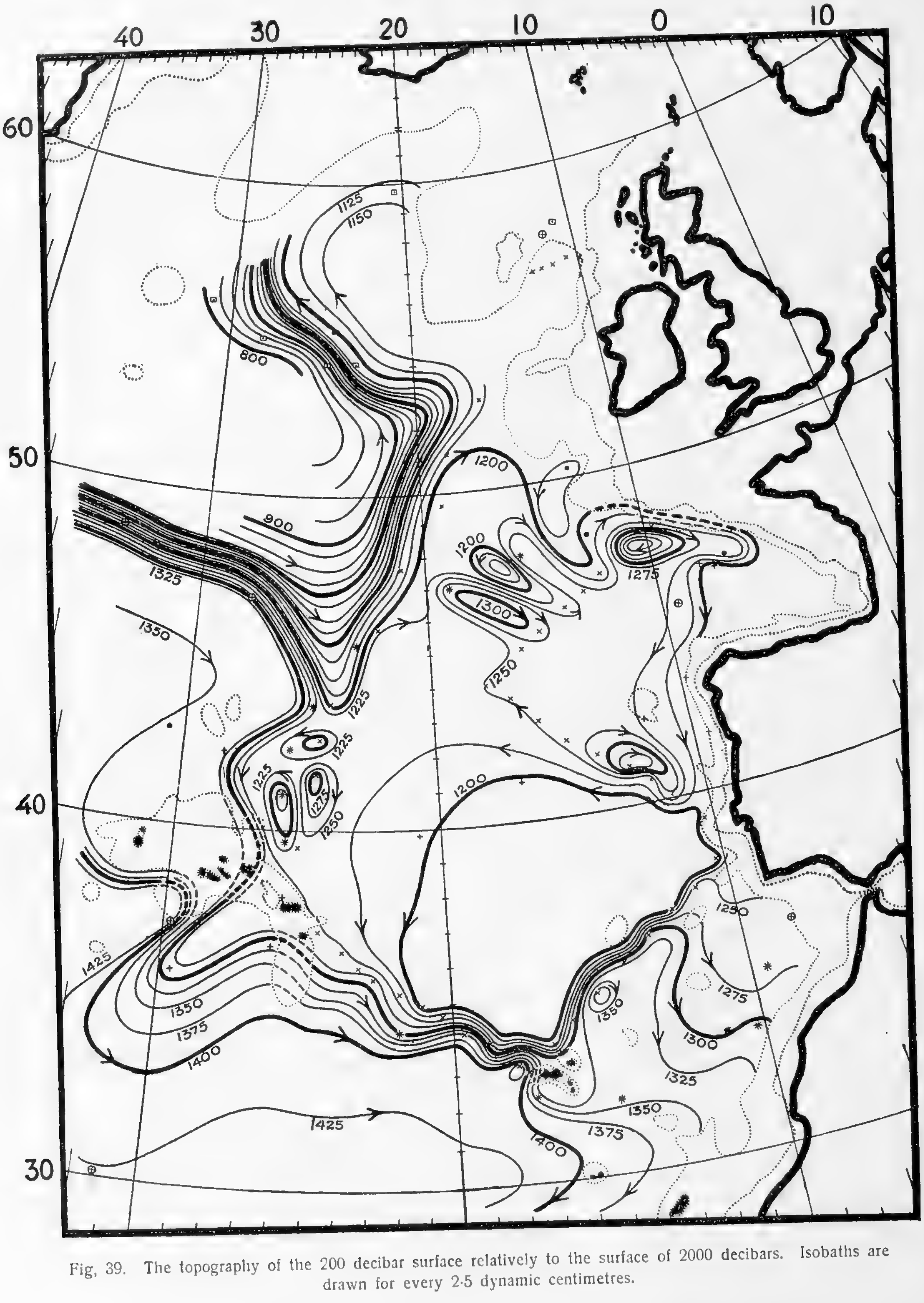


Fig. 39. The topography of the 200 decibar surface relatively to the surface of 2000 decibars. Isobaths are drawn for every 2·5 dynamic centimetres.

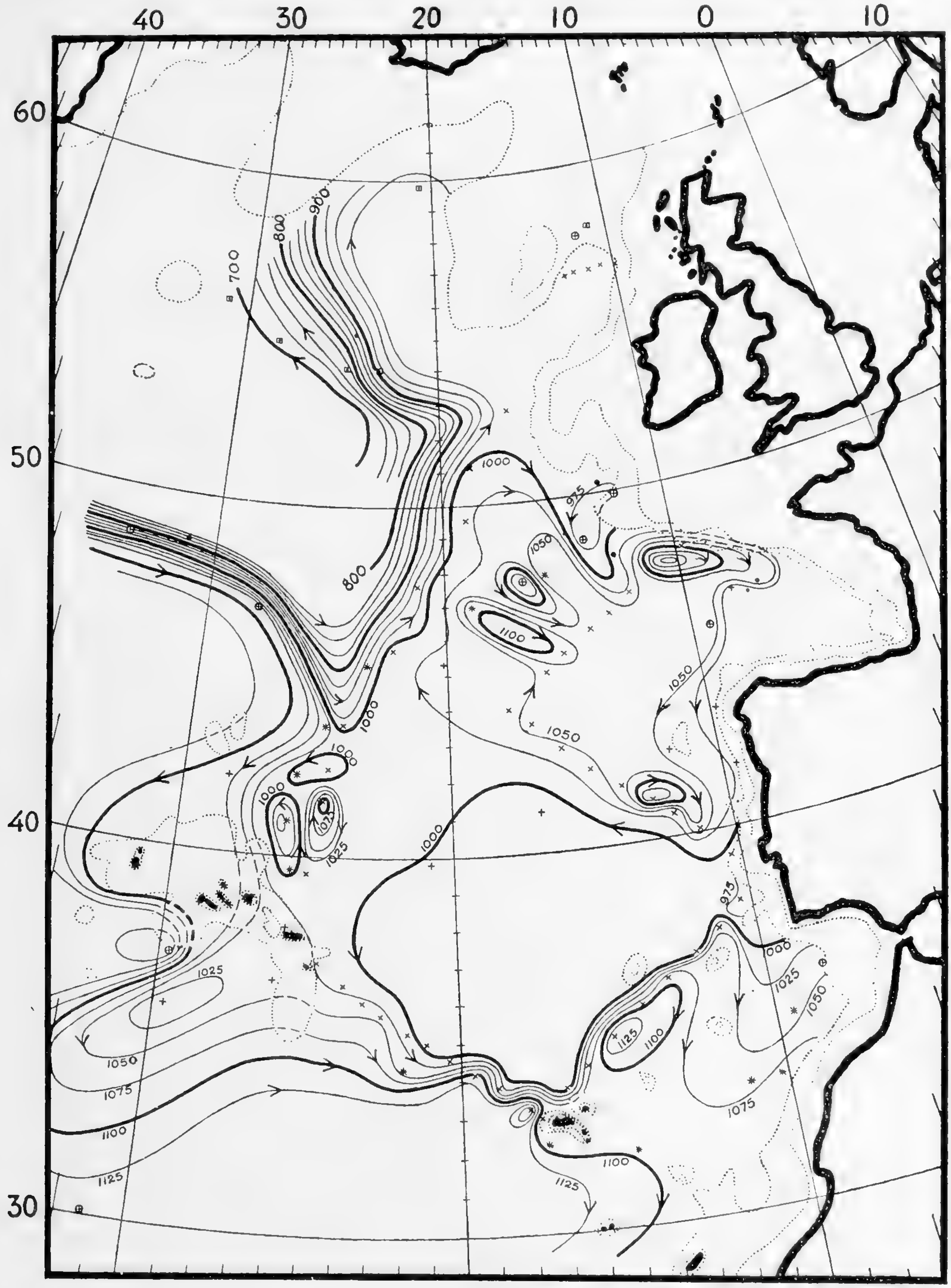


Fig. 40. The topography of the 400 decibar surface relatively to the surface of 2000 decibars.

rection, as applicable to the corresponding standard level surfaces (columns 6 and 7) or isobaric surfaces (columns 8 and 9). For the standard values of dynamic metres the density *in situ* (compression included) and the pressure are computed, and for those of pressure the specific volume *in situ* and the dynamic depth are found. The numerical calculations have been made by means of the tables published by V. BJERKNES and J. W. SANDSTRØM [V. BJERKNES, 1910]. Table IV contains anomalies of specific volume and depth of isobaric surfaces, found by subtracting from the actual values such values as would have been found if the temperature had been 0° C. and the salinity 35·0 ‰ everywhere in the sea.

The charts on p. 99* show the dynamic depth of different isobaric surfaces according to the observations on the "Michael Sars" Expedition and other expeditions in the North Atlantic. Dynamic isobaths are drawn for every 5 dynamic cms. They show the direction of the gradient currents at the different isobaric surfaces relatively to the currents at the surface. The difference in velocity between the sea surface and the isobaric surfaces is inversily proportional to the distance between the isobaths. If there were no currents at a surface of, for instance, 1400 decibars, the dynamic chart for this surface would approximately illustrate the currents in the surface water when the pure wind currents are not taken into account. Figs. 39 and 40 reproduce two dynamic charts for the eastern North Atlantic, dynamic isobaths being drawn for every 2·5 dynamic centimetres. They show the topography of the 200- and 400-decibar surfaces relatively to the surface of 2000 decibars and not to sea-level [HELLAND-HANSEN and NANSEN, 1926].

The dynamic charts illustrate quite well the agreement between different depths in accordance with the theorem of parallel solenoids. EKMAN's law of the connection between gradient currents and variations in bottom-depth seems to be verified in many places.

The conditions in the Faeroe-Shetland Channel are quite remarkable. It is a well-known fact that the distribution of temperature and salinity is very irregular in the Channel, and it has often been difficult to interpret it. As previously mentioned a comparatively large number of stations were worked in August 1910 from the "Michael Sars" and the "Goldseeker" (cf. section 22). The horizontal distribution of temperature and salinity at different depths is illustrated on p. 95*, and the corresponding topography of different isobaric surfaces is seen from the charts on p. 100*. Isobaths are drawn for every dynamic centimetre in the charts for 200, 400 and 600 decibars and for every dynamic decimetre in the charts for 800 and 1000 decibars. These charts indicate the existence of a series of eddies in the Faeroe-Shetland Channel. The Atlantic current comes from the west in the southern part of the Channel while another current comes from the north-west along the northern Faeroe banks. Now it is quite interesting to see the agreement between our dynamic charts of the Channel and the picture inserted on p. 100* illustrating an experiment once made by Professor KRÜMMEL [1911, Fig. 128]. KRÜMMEL's experiment was made by means of a water-tank, where the water was set in motion by air-blasts in the directions shown by the thick arrows in the figure. The intention was to demonstrate experimentally the currents in the central part of the North Atlantic between Africa and South America. The original illustration by KRÜMMEL is reversed, so that the right hand side of it comes to the left in our reproduction. The experiment showed the formation of a double eddy between the primary currents as well as an eddy on each side of them. The resemblance to the conditions in the Faeroe-Shetland Channel is striking. Our dynamic charts show a double eddy between the two main currents and another eddy farther to the north. The possible existence of an eddy in the south-eastern part of the Channel cannot be proved for lack of observations.

Having calculated the pressure at level surfaces or the dynamic depth of isobaric surfaces for different stations we can find, by means of the equations *(e)* and *(f)* in the preceding section, the vertical differences of the velocity-components of gradient currents. To facilitate the calculations the value of $\varkappa = {}^1/_2\, \omega . \sin\varphi$ is tabulated below for different latitudes.

$$10^{-4}\,\varkappa = 10^{-4}/2\;\omega . \sin\varphi$$

φ	0	1	2	3	4	5	6	7	8	9
0	∞	39·30	19·65	13·11	9·83	7·87	6·56	5·63	4·93	4·38
10	3·95	3·59	3·30	3·05	2·84	2·65	2·49	2·34	2·22	2·11
20	2·01	1·91	1·83	1·76	1·69	1·62	1·56	1·51	1·46	1·41
30	1·37	1·33	1·29	1·26	1·23	1·20	1·17	1·14	1·11	1·09
40	1·07	1·05	1·03	1·01	0·99	0·97	0·95	0·94	0·92	0·91
50	0·90	0·88	0·87	0·86	0·85	0·84	0·83	0·82	0·81	0·80
60	0·79	0·78	0·78	0·77	0·76	0·76	0·75	0·75	0·74	0·73
70	0·73	0·73	0·72	0·72	0·71	0·71	0·71	0·70	0·70	0·70
80	0·70	0·69	0·69	0·69	0·69	0·69	0·69	0·69	0·69	0·69

The anomalies of depth of isobaric surfaces recorded in Table IVB are expressed in 10^{-4} dynamic metres as a unit. In taking the differences of the values recorded for two stations we obtain numbers which, when multiplied by 10^{-4}, correspond to $D_1 - D_2$ in equation *(f)*. In order to explain the further calculations we may take the following example: In Table IVB we find a difference of 6175

between Stats. 68 and 66 for the isobaric surface of 1000 decibars. By equation *(f)* we find:

$$v'_{1000} = -10^{-4} \times \frac{(D_{66}-D_{68})\,10^4}{L} = -1{\cdot}08\,\frac{-6175}{100}$$
$$= 66{\cdot}7 \text{ cm./sec.},$$

which means that the gradient current at the surface has, normally to the straight line between Stat. 68 and Stat. 67, a component which is 66·7 centimetres per second greater than the corresponding component at about 1000 metres, both components being reckoned in such a direction that Stat. 68 is found to the right. Similarly we can find the differences of the velocity-components for various depths relatively to the water at about 1000 metres.

The five curves in Fig. 41 represent, in centimetres per second, such differences of velocity components between the levels represented by the ordinates p and the level for $p = 1000$ decibars. Each curve refers to the average condition between two particular stations, the numbers of which are written at the curve, beginning with the station on the left hand side of the current.

The curves I, II and III in Fig. 41 illustrate the conditions in the Great Atlantic Current south of the Newfoundland Banks, and curve IV the conditions in the current midway between America and Europe. Curve V illustrates the conditions in the sea west of the Bay of Biscay, where there is probably no strong gradient current but some eddies as shown in Figs. 39 and 40.

Curves I and II show a maximum of the velocity-components at about 25 metres below the surface. Dynamical calculations from other areas sometimes show a similar maximum at a short distance below the surface. This feature of the current is difficult to explain, but it may possibly depend partially on a comparatively great difference of direction between wind and gradient-current. As a matter of fact such differences of direction must be expected at the stations 66—69, where the gradient current alters its course very rapidly owing to the topography of the sea-bottom as already mentioned. But other ways of explanation may also present themselves.

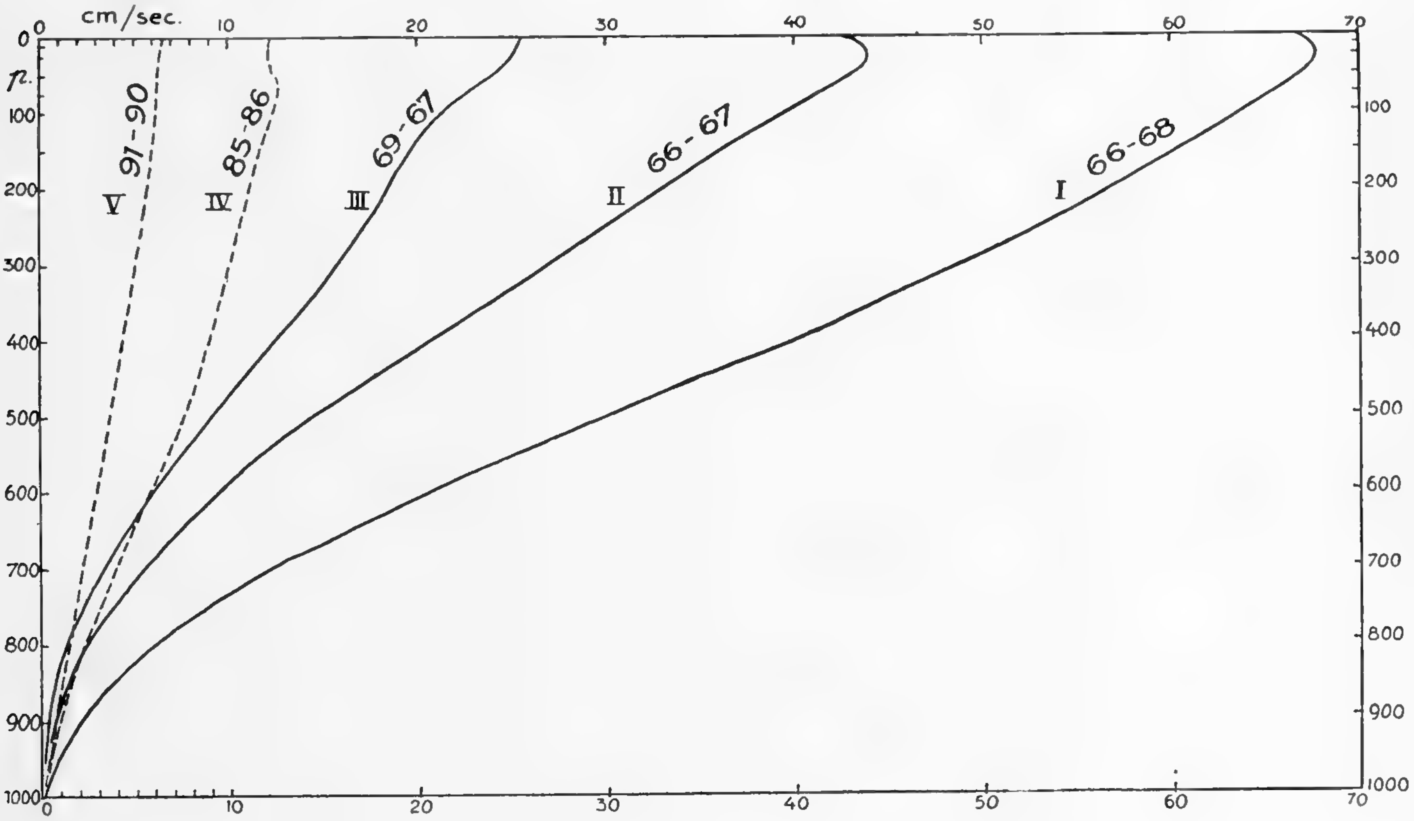


Fig. 41. Velocity components relatively to the components at 1000 metres depth.

Below the surface layers the velocity-components decrease with the depth at a different rate. Curve I shows a maximum of vertical variation at about 500 metres. Below 800 and 900 metres the vertical variations are comparatively slight, indicating that we here approach the lower boundary of the current. Similar conditions are also found with regard to curves II, III and IV.

Our computations have so far resulted in numerical values of the vertical variations of the velocity-components. If the dynamic isobaths in the isobaric surfaces may be

regarded as stream-lines, we can easily find the vertical variations of the velocity itself when we know the angle which the direction between the stations forms with the direction of the isobaths. This angle being β we have:

$$v_0 - v_p = - v'_p / \sin \beta,$$

where v_o is the average velocity of the current at the surface between the stations and v_p at the isobaric surface for p decibars, *i. e.* practically at a depth of m ordinary metres when m has the same numerical value as p. In order to ascertain the direction of the isobaths is it desirable to have a number of stations scattered over the area to be examined. An arrangement of the stations along one sectional line is unfit for the purpose. Between Stats. 66 and 68 the isobaths obviously go in a direction almost normal to the line between the stations, *i. e.* β is a wide angle and the velocity-components computed are nearly as large as the actual velocities. The line drawn from Stat. 85 to Stat. 86 (curve IV) evidently forms a small angle with the direction of the isobaths (the current) and the components are small in relation to the actual velocities. We should certainly have found much greater values if the stations had been worked straight across the current and not more or less along it.

Only very few of the "Michael Sars" stations were worked to such depths that we have observations past the lower boundary of the current. Even if the velocities are often small at about a thousand metres below the surface they are in most cases not negligible there. For instance between the stations 66 and 68 the difference of the velocity-components at about 1000 and 1400 metres is about 4 centimetres per second. In the eastern North Atlantic a sufficient number of stations down to 2000 metres or more has been worked, so we have been able to construct more reliable charts of the currents here than we can for other parts of the North Atlantic [Helland-Hansen and Nansen, 1926].

We need not enter into further detail regarding the numerical calculations of the currents. They are easily made by means of the equations above and the data given in Tables III and IV in Part II. We have here made the calculations by means of equation *(f)* in section 42; they may also be done by means of equation *(e)*. The numerical results will be a little different in the latter case, because there is a difference between the depth of the standard level surfaces and the standard isobaric surfaces.

X. CURRENT MEASUREMENTS.

44. Methods.

In 1906 a great many current measurements were made in the deep Norwegian fjords, in the Norwegian Sea and the North Sea [Helland-Hansen, 1907]. A rowing-boat was tightly anchored fore and aft with heavy grapnels and hemp-lines. In the fjords we could obtain very sharp cross-bearings whereby the shifting of the boat's position within a metre or two could sometimes be discovered. The boat kept its position so well that its drift had no effect on the observations of the currents even if the depth to the bottom was as much as 500 metres.

It was part of the program for the hydrographic investigations on the "Michael Sars" Expedition to have current measurements made in different localities. We intented to use one of our rowing-boats with double anchoring in places where the bottom-depth was not great. The first experiments of this kind were made at *Stat. 18* in the Straits of Gibraltar, where a few observations were secured from the rowing-boat. The current, however, proved to be so strong that the hemp-lines broke again and again, and the plan had to be given up. We had not the necessary equipment for replacing the hemp-lines by steel wires, as we have had when making more recent observations of the currents in the open sea, for instance on the "Armauer Hansen" Expedition to the North Atlantic in 1913.

Having been forced to give up the work from the small rowing-boat we tried to anchor the steamer by dropping one of the ship's anchors attached to the thick trawl-wire. In the strong and fairly regularly veering current the vessel lay steady enough to allow fairly reliable measurements to be made. The stout steel wire served to check the ship's movements. In order to obtain an idea of what the latter amounted to the ship's compass was read at short intervals. These compass readings did not vary much, even over a considerable length of time. The ship mostly remained lying in one direction, at least during the time needed for carrying out each separate observation. Of course the compass readings do not enable us to judge of the distance which the vessel may have drifted. Naturally the sheering of the ship to or from the anchor does not affect the bearing. Even if a swing of the vessel is immediately indicated

by the compass readings the way made by the ship when swinging cannot be determined without knowing the distance from the bow to the anchor, *i. e.* the position of the anchor-wire in the water. A swing of the ship may have but a comparatively little influence upon the measurements if the wire remains in a constant position.

At *Stat. 58*, S. of the Azores, the ship had been trawling when the trawl got stuck to the bottom in a place where the bottom-depth was about 950 metres. In this way the ship was well anchored, and we took advantage of the opportunity to make current measurements.

In a few cases observations with the current-meters were made from the "Michael Sars" when it was drifting. At *Stat. 49 C* a plankton-net of 3 metres diameter was suspended by the trawl-wire at a depth of 1 000 metres. The depth to the bottom was probably more than 5 000 metres. The big net and wire reduced the ship's movements. Many observations were made at 9 metres below the surface, while at the same time measurements were made at other levels down to 1 000 fathoms. At *Stats. 19 C* and *47* a few measurements were made while the ship was being slowly moved by the propeller at a fairly constant speed.

The observations at the three last stations were intended to give some idea of the vertical differences of velocity, not, of course, of the velocities themselves.

The observations were made with EKMAN's propeller current-meter. 4 instruments were used. Their constants are seen from the following equations:

Instrument No. 7: $v = 0{\cdot}6 + 0{\cdot}64\ n$
" " 30: $v = 0{\cdot}5 + 0{\cdot}39\ n$
" " 31: $v = 0{\cdot}7 + 0{\cdot}37\ n$
" " 41: $v = 0{\cdot}5 + 0{\cdot}38\ n$,

where v means the velocity in centimetres per second and n the number of revolutions per minute. Sometimes two instruments were used simultaneously at the same depth and showed a good agreement mutually.

The results of the observations are recorded in *Table V* where some particulars are also given of the circumstances in which the measurements were made. The times recorded in the second and third column of this table are the actual mean times of the observations. Besides the observed velocity a reduced velocity is given, the spreading of the shots being taken into account. The reduced velocity refers to the average velocity in the mean direction.

The iron masses of the ship may appreciably affect the compass of the current-meter at small depths. The magnitude of the effect — the 'deviation' — naturally depends on the magnetism of the ship and varies with the ship's heading. According to investigations made by LOTTE MØLLER, A. SCHUMACHER and H. THORADE we may infer that the magnetic influence of a ship like the "Michael Sars" reaches down to about 30 metres below the surface. At 9 metres — where many measurements have been made — the deviation in some cases amounts to 10° or more. The error in the determination of the direction of current at 5 metres is considerably greater, when the observations are made from the "Michael Sars" and not from the rowing-boat. I have not tried to correct our observations for such errors.

Even if the current-meters were rather heavily loaded with lead weights the line was sometimes deflected to an appreciable extent by the strength of the currents. Such cases are noted in the tables.

When the current measurements have been made during a sufficient length of time to allow of harmonic analysis, the N.- and E.-components have been computed by interpolation for every complete lunar hour. We have not sufficient observations from any of the stations to enable us to find the diurnal variations of the currents; but at Stats. 18 and 58 measurements were made during more than 12 hours, so the semi-diurnal variations can be calculated. For the N-component we have the following equation:

$$v = \bar{v} + P \cos 30\,t + Q \sin 30\,t$$

and for the E.-component

$$u = \bar{u} + M \cos 30\,t + N \sin 30\,t$$

where $\bar{v}$ and $\bar{u}$ mean the average values of the components for 12 lunar hours. t is the time (in lunar hours) reckoned from the first hour of observation. If, for instance, the observations commence with 22 L. H., t is equal to O for this hour, 1 for 23 L. H. etc.

For determination of the major ($2\,a$) and minor ($2\,b$) axis of the ellipse representing the tidal current we have the following equations [WERENSKIOLD, 1916]:

$$2\,a = \sqrt{(M+Q)^2 + (N-P)^2} + \sqrt{(M-Q)^2 + (N+P)^2}$$

$$2\,b = \sqrt{(M+Q)^2 + (N-P)^2} - \sqrt{(M-Q)^2 + (N+P)^2}$$

If b is negative the tidal-current turns *cum sole*, if positive *contra solem*.

The angle, α, which the major axis forms with the W. and E. direction (positive from E. towards N.) is found by the equation:

$$tg\,2\,\alpha = \frac{2\,(M.P + N.Q)}{(M+Q)\,(M-Q) + (N+P)\,(N-P)}$$

The time when the maximum of current occurs may be expressed in degrees (γ) reckoned from the starting point of the analysis, and found by the following formula:

$$tg\,2\,\gamma = \frac{2\,(M.N + P.Q)}{(M+Q)\,(M-Q) - (N+P)\,(N-P)}$$

The results of the calculations of the angles may be checked by means of the equation:

$$tg\,(\alpha - \gamma) = \frac{P - N}{M + Q}$$

45. Measurements from Anchored Ship.

Observations from the "Michael Sars" at anchor were made in the Straits of Gibraltar (Stat. 18) and in the sea S. of the Azores (Stat. 58) as mentioned in the preceding section. The reduced velocities recorded in Table V and the mean directions are represented by diagrams on pp. 101* and 102*. The thick lines drawn in full illustrate the observations at 9 metres. Observations at other depths are denoted by crosses, with numbers for the depths. The thin lines marked "M. S." show the true (not magnetic) heading of the ship.

At both stations measurements were made during more than 12 hours. At 9 metres so many observations were made that harmonic analysis of the semi-diurnal variations can be made. As previously mentioned, the deviation of the compass of the current-meter has not been taken into account.

α. *Observations in the Straits of Gibraltar.*

It is well known that a surface current carries Atlantic water into the Mediterranean, while an under-current flows in the opposite direction and brings deep water from the Mediterranean into the Atlantic. The two currents are clearly demonstrated by the figure on p. 101*.

The observations from the "Michael Sars" commenced early in the morning of the 30th of April, when the surface current was running W., with the ship pointing E. The velocity of the current at 9 metres was 40—50 cm./sec. or nearly 1 knot (towards W.) Shortly afterwards, at about 4 o'clock in the morning, the surface current turned and the ship swung round. Later on until noon the direction of the ship remained fairly constant towards W., while the current at 9 metres ran eastwards with a maximum velocity of 115 cm./sec. (2·2 knots) at about 9 o'clock. In the afternoon the ship swayed somewhat in accordance with the surface current, but neither of them turned round. The conditions in the early morning and the early afternoon showed a marked difference which did not correspond to the variations in wind at this place (cf. the notes on the weather, p. 54*), but indicates diurnal or other variations of a longer period than 12 hours.

The measurements from the rowing-boat were made at 17—18 o'clock on the 29th of April not far from the place where the "Michael Sars" was anchored some hours afterwards. Observations were made at 5, 20 and 40 metres. The velocities were almost the same at these three depths and greater than the maximum velocity found at 9 metres in the forenoon on the following day. This, again, indicates considerable diurnal variations.

Fig. 42 shows the variations of the N.- and E.-components of the current at 9 metres. By means of the smoothed curves the values of the components have been interpolated for every lunar hour, beginning with 22 L.H. The values thus found have been used for an harmonic analysis which has resulted in the following equations:

$$v = 22{\cdot}7 - 35{\cdot}9\ cos\ 30\,(H+2) + 4{\cdot}6\ sin\ 30\,(H+2)$$

$$u = 46{\cdot}9 - 54{\cdot}8\ cos\ 30\,(H+2) - 2{\cdot}5\ sin\ 30\,(H+2)$$

where H means the lunar hour.

The results of this analysis are illustrated in Fig. 43. The ellipse represents the variations of a semi-diurnal tidal current, which turns *cum sole*. It has its maximum (65·5 cm./sec.) towards N 57° E ($\alpha = 33°$) at 4 and 16 L. H. and towards S 57° W at 10 and 22 L. H. The velocity of the rest current is $= \sqrt{22{\cdot}7^2 + 46{\cdot}9^2} = 52$ centimetres per second (1 knot) towards N 64° E. This current is represented by the arrow pointing towards the centre of the ellipse in Fig. 43. The resultant current (the semi-diurnal tidal current + the rest current) at different lunar hours is found by drawing straight lines from the rear point of the arrow to the different points marked along the ellipse. The maximum of this resultant current appears about 4 hours after the passage of the moon, with at velocity of 118 cm./sec. towards N 60° E.

These results are, however, uncertain because the observations comprise 12 lunar hours only. The curves in Fig. 42 show considerable variations besides the semi-diurnal one. It is very probable that variations with shorter periods than 12 lunar hours exist, but there are evidently variations of a longer period too. When the semi-diurnal variations are eliminated we obtain a residual variation which manifests itself by a general increase of the E.-component and decrease of the N.-component during the period of observation. This variation may be caused by a diurnal period in the tidal currents or by meteorological changes, or both. In any case it

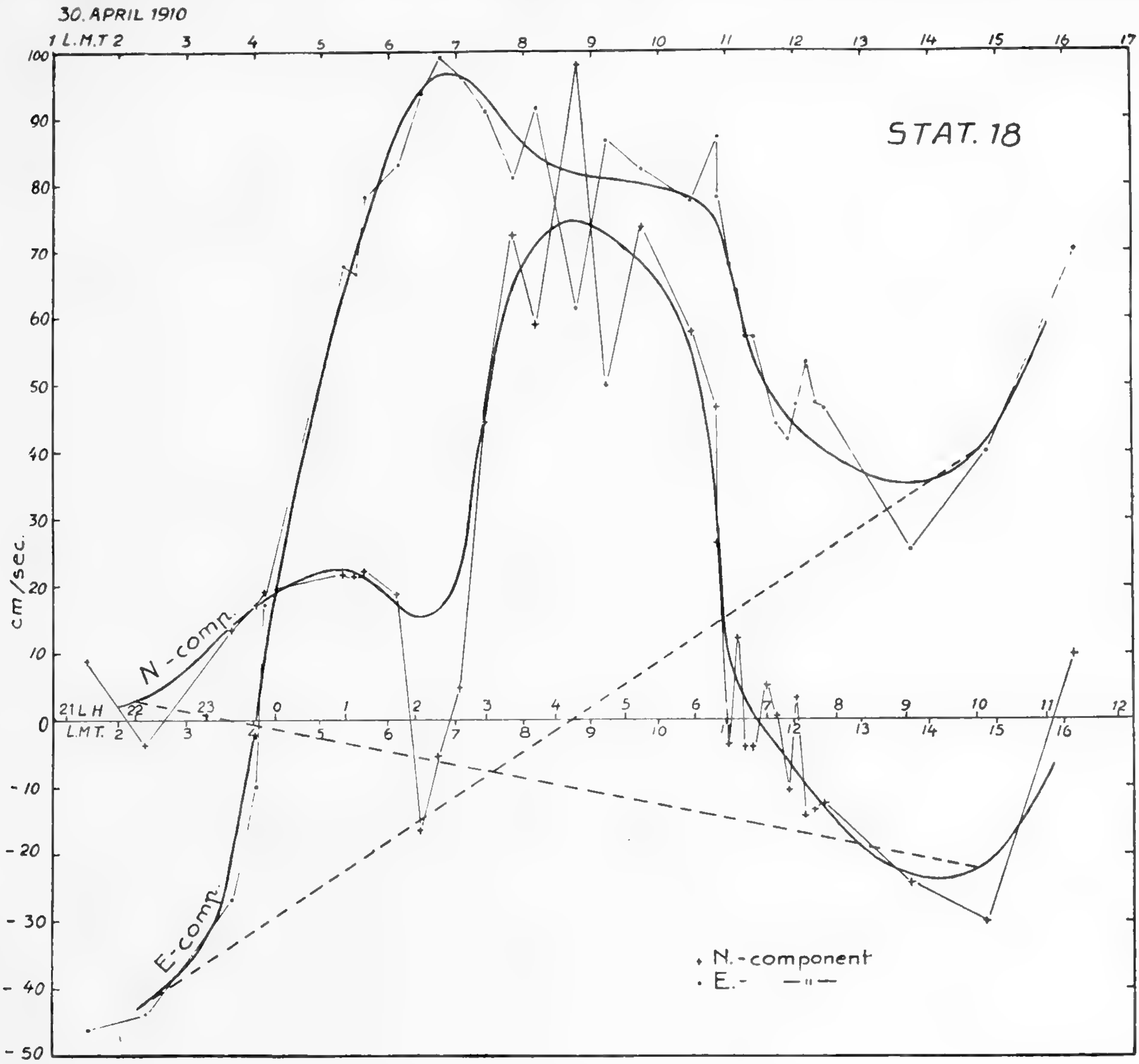


Fig. 42. The N.- and E.- components of the current at Stat. 18, 9 metres.

affects the results of the harmonic analysis with regard to the semi-diurnal variations and the rest current.

The broken lines in Fig. 42 connect points (for 22 and 10 L.H.) which would have been found along the same ordinates if the current had been composed of a constant rest current and a semi-diurnal tidal current only. The variations with a longer period than 12 lunar hours are certainly not linear, but we may to some extent eliminate them in our analysis of the semi-diurnal variations by taking them as linear. We can then reduce the hourly values which were used in the harmonic analysis above. In doing so we obtain the following equations:

$$v = 21{\cdot}6 - 38{\cdot}0 \cos 30\,(H + 2) - 3{\cdot}3 \sin 30\,(H + 2)$$
$$u = 50{\cdot}3 - 47{\cdot}9 \cos 30\,(H + 2) + 23{\cdot}3 \sin 30\,(H + 2)$$

This gives a rest current with a velocity = 55 cm./sec. towards N 67° E, and a maximum of the semi-diurnal tidal current = 63·5 cm./sec. towards N 56° E and S 56° W. So far, the results are nearly the same as those found by the first analysis, but in other respects the results differ. The maximum ot the semi-diurnal tidal current appears $3^1/_2$ and not 4 lunar hours after the passage of the moon. While the major axis of the ellipse is almost the same in both cases, the minor axis comes out a good deal greater with the reduced than with the original values. The most striking difference between the results of the two calculations is, however, that the second analysis gives a semi-diurnal tidal current which turns *contra solem*, while the first gave a turn *cum sole*. The

result first obtained corresponds to the swing of the ship early in the morning (30. April) but it is possible that the diurnal variations have a decisive influence upon the direction of the turn.

If the average variation of the current in 12 lunar hours (represented by the broken lines in Fig. 42) is due to *diurnal tidal variations* these must be very important and able of themselves to cause a current with a maximum velocity of at least 43 cm./sec., but probably more. In this connection I may refer to the results arrived at in section 26.

coast and the outlet of the fjord, thus temporarily hindering the outward movement of the surface water of the fjord. Similarly, variations in the air-pressure and winds on both sides of the Straits of Gibraltar must cause variations of the currents in the Straits. I do not possess the necessary observations for a further study of the variations of these currents and cannot therefore decide how far the above-mentioned increase of the surface current in the Straits during the time of observation is caused by meteorological changes or diurnal tidal variations.

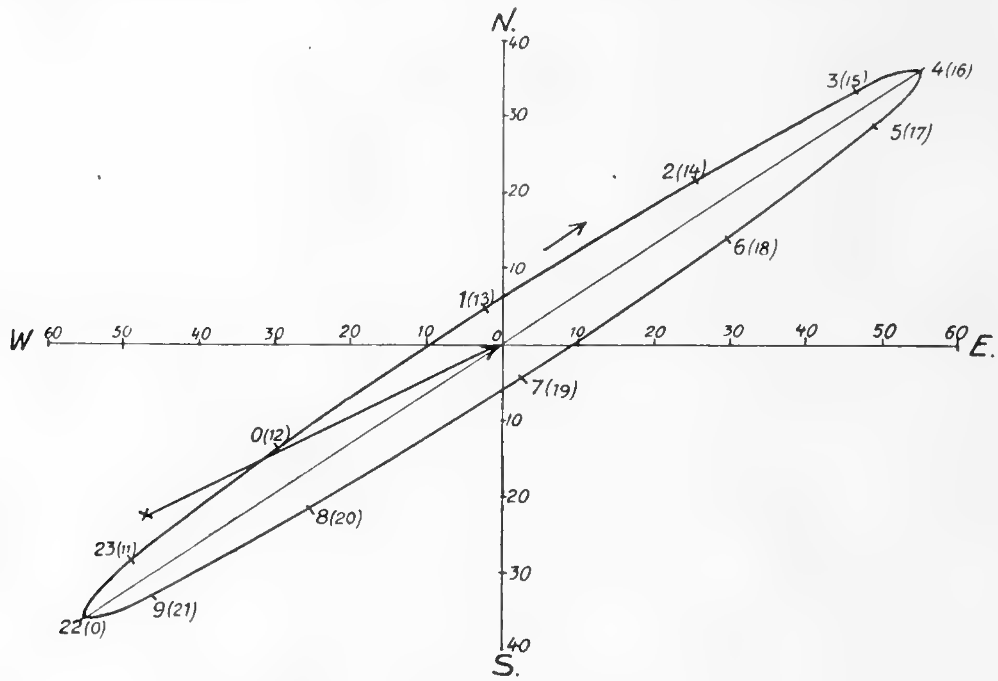


Fig. 43. The current at Stat. 18, 9 metres.

The average variation in question may, however, also be caused by *changes in the meteorological conditions.* The author has found that some great variations in the surface current usually running seawards in the Sognefjord seem to agree with variations in the mean air-pressure gradient over the North Sea outside the fjord. The wind blows nearly at a right angle *cum sole* from the direction of the pressure gradient. The wind, on its part, creates a wind current which causes an average transport of the upper water-layers at a right angle *cum sole* from the wind, *i. e.* in a direction contrary to that of the air-pressure gradient. Current measurements were made in the Sognefjord during 60 hours in July 1929, and on that occasion the surface current happened to slacken very markedly in the course of 20—30 hours which could not be explained by the local wind conditions. Shortly before, however, the mean air-pressure gradient over the northern North Sea veered from north to west, whereby the surface water was probably driven more and more towards the

We have seen that occasionally the upper current may turn and run westwards owing to the tidal streams. Our observations show no turning of the under-current at, for instance, 200 metres, but great variations in its velocity. The surface current (or the upper current) and the under-current are naturally defined in accordance with the rest-current at different levels. We are not able to calculate the rest-current except at 9 metres, and even there only approximately. We may, however, use the vertical distribution of salinity as a criterion of the vertical extension of the two currents.

Vertical series of observations on salinity and temperature were made at four different times at Stat. 18 (Table II, pp. 22* and 23*). The first series, 18A, which is the most complete one, is used for the more detailed records in Table III (p. 35*) and the curves reproduced on p. 66*. The stability was very pronounced in the upper 75 metres, and especially between 25 and 50 metres, where the vertical variation of salinity was great. The salinity was a little

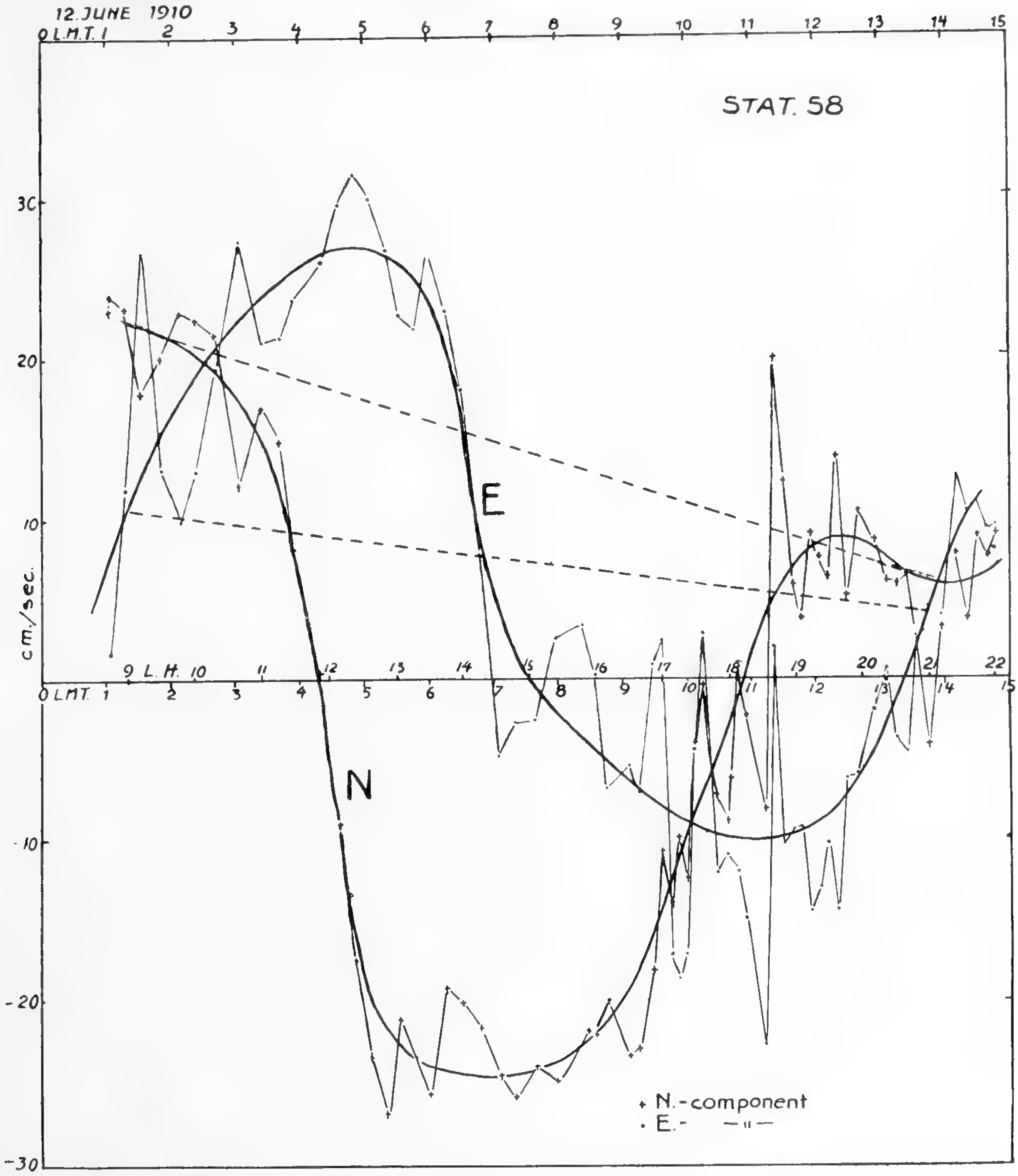


Fig. 44. The N.- and E.-components of the current at Stat. 58, 9 metres.

more than 36‰ above the discontinuity layer and more than 38‰ below it. We may, then, take 37‰ (and 14° C) as a limit, and reckon water with lower salinity (and higher temperature) as belonging to the upper current. The series 18A and 18B were obtained on 29. April between 11^h and 12^h, and at about 14^h L. M. T. From the current measurements made on the following day we may infer that the upper current was weak when Stats. 18A and 18B were worked. 37‰ and 14° C. was found at about 35 metres in the first series and at about 30 metres in the second. The series 18C and 18D were obtained at times when the upper current was stronger (18 D at the time of maximum velocity), and 37‰ or 14° C appeared at much greater depths (about 100 metres). There are evidently great tidal variations in the vertical extension of the two currents.

The figure on p. 101* seems to show that the water between 150 and 250 metres moved westwards during the whole period of observation. The maximum velocity

observed in the under-current was 245 centimetres per second (corresponding to nearly 5 knots) at 200 metres at 2 o'clock in the morning 30. April (about 22 L. H), when the resultant current at 9 metres ran westwards too, with a velocity of 45 cm./sec. At this time probably all the water from the surface to the bottom moved from the marks for different depths, do not pretend to illustrate the variations with even approximate correctness. The curve for 40 metres, for instance, can be drawn in such a way that it shows variations similar to those at 70 metres. From our observations of salinity, mentioned above, it seems probable that the boundary between the upper and

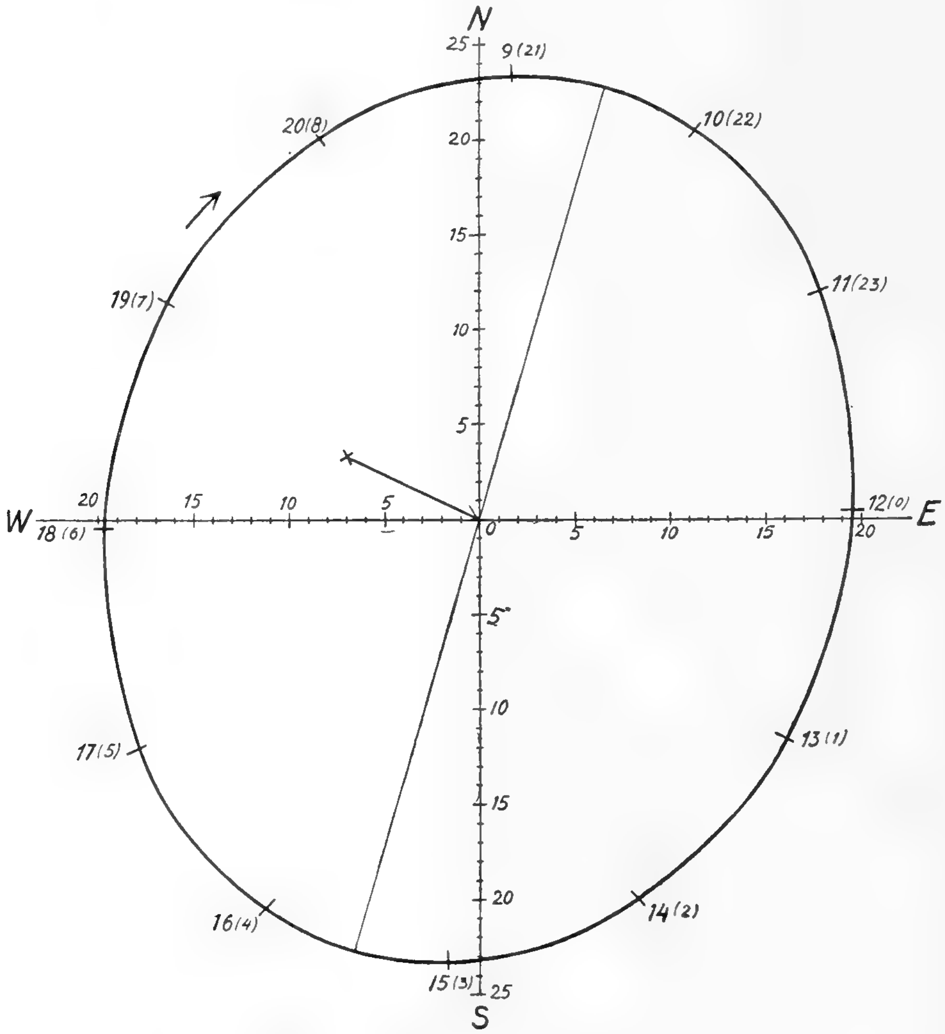


Fig. 45. The current at Stat. 58, 9 metres.

Mediterranean to the Atlantic. We cannot now decide the question whether the whole mass of water occasionally moves in the opposite direction.

Our observations show that *the velocity of the under-current had a maximum when that of the surface current had a minimum, and vice versa. When one of the currents was strong it attained also a comparatively great vertical extension.* Some observations from 70 metres show that the water at this depth belonged sometimes to the surface current and sometimes to the under-current. The broken curves in the graph on p. 101*, combining the under current shifted at least from 30 metres to 100 metres on 29. and 30. April 1910.

β. Observations in the Sea S. of the Azores.

The observations on 12. June at Stat. 58 are plotted out in the figure on p. 102*. The curve marked "M. S" shows that the direction of the ship usually varied rather slowly (except between 9^{30} and 11^{30} o'clock). The variations took place within comparatively narrow limits while the current at 9 metres turned completely round. The heading of the ship naturally depends on both current

and wind, according to their relative strength. Notes on the wind are found on p. 60*. At 2^h 40^m the wind and the current (at 9 metres) had almost the same direction, about 180° different from the heading of the ship. At 5^h 30^m the surface current was evidently near its maximum (at 9 metres between 30 and 35 cm./sec.); the ship then had a position which can easily be explained by the composite action of current and wind. At 11^h 30^m the current was weak and the ship lay directly against the of 24 cm./sec. and a minimum of 19 cm./sec. according to the analysis above. The maximum occurs $2^1/_2$ hour before and $3^1/_2$ hour after the passage of the moon; the direction is then N 16° E or S 16° W. This semi-diurnal tidal current rotates *cum sole.*

As at Stat. 18, the N.- and E.-components at Stat. 58 show an appreciable average variation during 12 lunar hours as indicated by the broken lines in Fig. 44. Both components show lower values at 21 L. H. than at 9 L. H.,

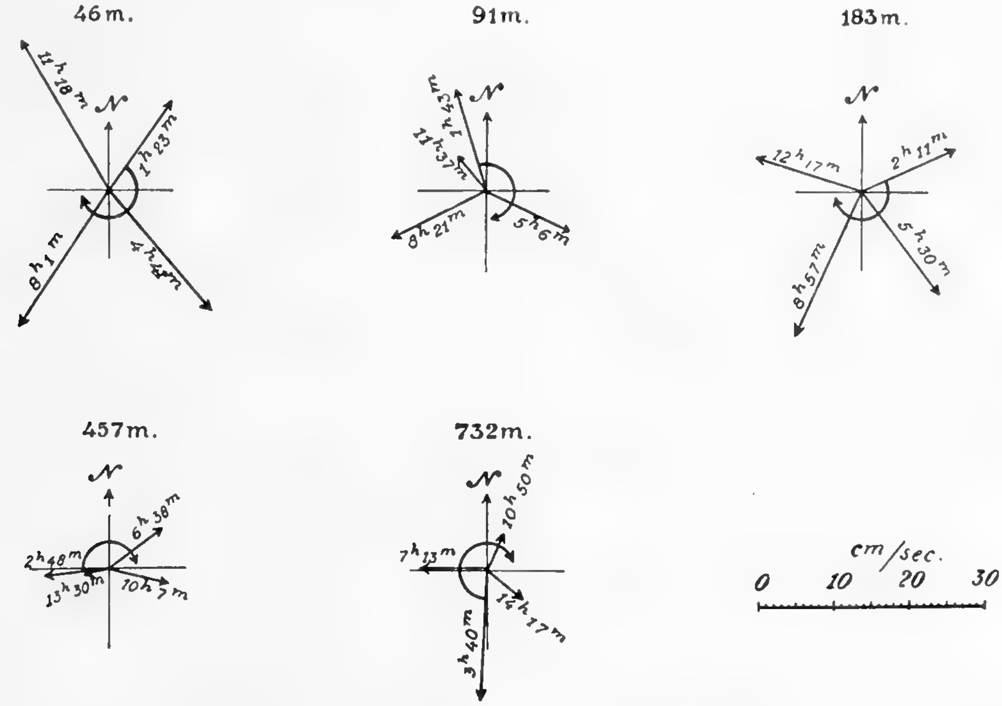


Fig. 46. The currents at various depths at Stat. 58.

wind. — The variations in the heading of the ship between 9^{30} and 11^{30} o'clock coincided with comparatively large variations in the observed velocity and direction of the current, the observations having then probably been influenced to a considerable degree by the ships's movements. Otherwise the current measurements seem to be fairly reliable.

Fig. 44 illustrates the variations of the N.- and E.-components of the current at 9 metres. When the hourly values of the components are used without reduction the harmonic analysis beginning with 9 L. H. (1^h 20^m L. M. T.) results in the following equations:

$$v = -3{\cdot}3 + 23{\cdot}4 \cos 30\,(H+3) + 0{\cdot}5 \sin 30\,(H+3)$$
$$u = 7{\cdot}0 + 1{\cdot}7 \cos 30\,(H+3) + 19{\cdot}7 \sin 30\,(H+3)$$

This gives a rest-current with a velocity of 8 centimetres per second towards S 64° E. It is weak compared with the semi-diurnal tidal streams which have a maximum the difference being especially great as regards the N.-component. When we reduce the hourly values for this average variation in the same way as is done for the observations at Stat. 18, we obtain the following results:

$$v = -3{\cdot}9 + 22{\cdot}3 \cos 30\,(H+3) - 3{\cdot}6 \sin 30\,(H+3)$$
$$u = 6{\cdot}8 + 1{\cdot}1 \cos 30\,(H+3) + 17{\cdot}8 \sin 30\,(H+3)$$

This means a rest-current of 8 centimetres per second towards S 60° E, *i. e.* practically the same values as were found by the first analysis. The maximum of the rotatory tidal current amounts to 23 cm./sec. and the minimum to 18 cm./sec. The maximum current appears one hour earlier than the time found above, but the rotation goes in the same direction *(cum sole).*

The average variation from 9 to 21 L. H. may be caused by tidal changes with a diurnal period or by changes in air-pressure and wind over a wide area, as was the case in the Straits of Gibraltar. If this variation at Stat.

58 is due to variation of the tides, a current with a diurnal period and a maximum velocity of at least 9 cm./sec. must be superposed on the one with a semi-diurnal period.

The observations here discussed leave room for no doubt as to the existence of fairly strong tidal currents in the upper water-layers in the open sea at a considerable distance from the Azores. The depth to the bottom was about 950 metres at Stat. 58, as mentioned above. The Station was situated in a locality where the bottom sloped from the Azoric sub-marine platform towards the deep sea in the south. It is to be expected that the velocity of the tidal currents should increase in such a locality, but it is nevertheless remarkable that they are as important as our observations show.

The measurements made at depths greater than 9 metres are illustrated in the graph on p. 102*. They are too sparse to allow of a satisfactory analysis. The variations in the observed velocity and direction of the current at different levels do not agree with the variations in the heading of the ship, and the movements of the latter have not had a decisive influence upon the results of the measurements so far as one can judge from the scattered observations.

In Fig. 46 the results for 46, 91, 183, 457 and 732 metres are illustrated by means of vectors. At each of these depths 4 observations were made. It seems fairly sure that the current at all levels turned *cum sole,* and that a complete turn took place in the course of about 12 hours. This evidently means that the rotatory tidal currents dominated at all depths. They were not equally strong or running in the same direction at the different levels.

Such variations of the tidal currents from one level to another support the conclusions arrived at in Chapter V. We shall not go further into the subject here. A more thorough discussion of the interesting problems that arise must be left for the future when a great deal more material in the form of observations has been procured.

46. Measurements from Drifting Ship.

The current measurements made at Stats. 19C, 47 and 49C will not be discussed in detail. They only serve to demonstrate a few facts of interest with regard to the variations according to depth.

The observations at *Stat. 19C* were made when the ship was moving slowly eastwards (with the trawl at the bottom). The station was situated in the Mediterranean at a short distance from Gibraltar.

The current-meter at 300 metres registered a velocity of about 60 cm./sec. and a direction contrary to that in which the ship was drifting. It is probable that the current-meter here acted almost like a log. At 5 metres the

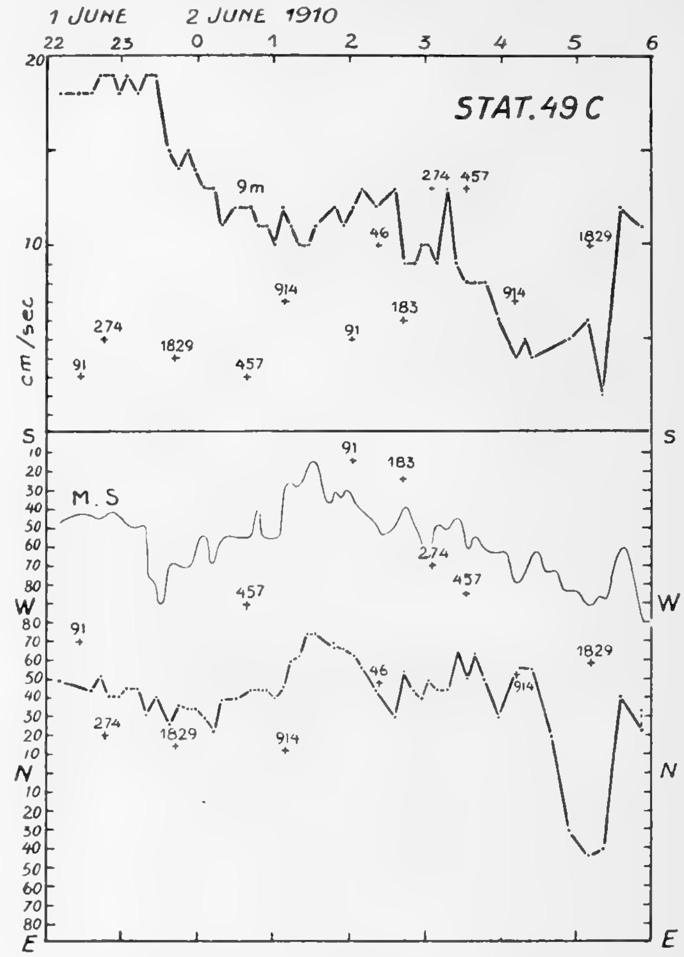


Fig. 47. Relative velocities and directions observed at Stat. 49 C.

deviation of the compass of the instrument makes the observations unreliable, but it seems fairly certain that the apparent current ran eastwards at a considerable velocity (about 60 cm./sec.). This means that the surface current had a real velocity of more than 1 metre per second towards E. at the time of observation, which corresponds to the time when the surface current in the Straits of Gibraltar had passed its maximum but still ran strongly eastwards. At 20 metres the current was deflected to the right in relation to the current at 5 metres, and at 40 metres it was still more deflected. At both of these depths the current moved eastwards at a greater speed than the ship. At 80 metres the apparent current ran towards SW at $1^h\ 16^m$, the real current probably running SE at a speed considerably less than at higher levels. At $3^h\ 4^m$ the indication of the current-meter at 80 metres seems nearly to correspond to the movement of the ship, as is also the case with the observation at 170 metres.

At *Stat. 47* a few measurements were made when the trawl was hauled and the ship moving slowly. The directions registered by the current-meter were nearly opposite to the heading of the ship, the greatest difference (26°)

between the registration and heading being found at 9 metres. There seems to be a difference in the currents between the various levels of the observations, but the currents were probably rather weak.

At *Stat 49 C* two current-metres were used simultaneously, one at 9 metres and another at different depths lower down as far as 1829 metres (1000 fathoms). The results are plotted out in ordinary Carthesian co-ordinates in Fig. 47. The movements of the ship were reduced by means of a big net suspended by the trawl-wire at a depth of 1000 metres. The depth to the bottom was about 5000 metres

The heading of the ship varied between S. and W. (curve marked "M. S."), while the observations at 9 metres exhibit variations in the direction of the apparent current, mostly between W. and N., *i. e.* about 90° different from the ship's direction. The two curves show almost the same variations.

The velocities observed show considerable variations with the depth. During the first two hours of observations the velocities were 10—15 cm./sec. greater at 9 metres than at 91, 274 and 1829 metres while the directions recorded were pretty nearly the same at all 4 depths. The velocity at 9 metres decreased fairly evenly during 6—7 hours, while at the other levels the registered velocity showed a general increase.

The deepest observations are two from 1829 metres. If we suppose that the real rest-current at this depth is negligible, the movement of the ship can be determined and eliminated from the observation simultaneously made at 9 metres. In so doing we find that the current at 9 metres at $23^h\ 42^m$ L. M. T. on the 1st of June 1910 had a velocity of 11 cm./sec. towards N 38° W, and at $5^h\ 11^m$ on the 2nd of June 12 cm./sec. towards S 86° E. This indicates that there are *rotatory tidal currents which have a different velocity and direction at different levels, and that the tidal currents may be quite distinct and measurable even if the depth to the bottom is very great.*

LITERATURE.

1915. ÅNGSTRÖM, ANDERS: A Study of the Radiation of the Atmosphere. *Smithsonian Miscellaneous Collections*, Vol. 65, No. 3. Washington 1915.

1898. BJERKNES, V.: Ueber einen hydrodynamischen Fundamentalsatz und seine Anwendung besonders auf die Mechanik der Atmosphäre und des Weltmeeres. *Kungl. Svenska Vetenskaps-Akademiens Handlingar*, Vol. 31, No. 4. Stockholm 1898.

1901. BJERKNES, V.: Cirkulation relativ zu der Erde. *Øfvers. af Kungl. Vet. Akad. Förhandl. 1901*, No. 10. Stockholm 1901.

1910—11. BJERKNES, V.: Dynamic Meteorology and Hydrography. Edited by *The Carnegie Institution of Washington*. Part I, Statics; Part II, Kinematics. Washington D. C. 1910 and 1911.

1909. BRENNECKE, W.: Ozeanographie. *Forschungsreise S.M.S. "Planet" 1906—1907*. Herausgegeben vom Reichs-Marine-Amt. Band III. Berlin 1909.

1913. BRENNECKE, W.: Beobachtungen über Temperaturschwankungen in den Tiefenschichten des Atlantischen Ozeans. *Annalen der Hydrographie und Maritimen Meteorologie*, Berlin 1913.

1921. BRENNECKE, W.: Die ozeanographischen Arbeiten der Deutschen Antarktischen Expedition 1911—1912. *Aus dem Arkiv der Deutschen Seewarte*, XXXIX, 1921, No. 1. Hamburg 1921.

1895. BUCHAN, ALEXANDER: Report on Oceanic Circulation etc. *Report on the Scientific Results of the Voyage of H.M.S. Challenger during the years 1872—76*. Summary of the Scientific Results, Part II, London 1895.

1927. BÖHNECKE, G.: Die Bodenwassertemperaturen bei der Romanche-Tiefe. Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor" 1925 bis 1927. *Zeitschr. Ges. f. Erdkde.* Berlin 1927.

1928. DEFANT, ALBERT: Die systematische Erforschung des Weltmeeres. *Sonderband der Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Hundertjahrfeier 1828—1928.* Berlin 1928.

1919. DORNO, C.: Physik der Sonnen- und Himmelsstrahlung. *Die Wissenschaft*, Bd. 63. Braunschweig 1919.

1905. EKMAN, V. WALFRID: On the Use of Insulated Water-Bottles and Reversing Thermometers. *Publications de Circonstance*, No. 23. Copenhagen 1905.

1910. EKMAN, V, W.: Tabellen für Meerwasser unter Druck. *Publications de Circonstance*, No. 49. Copenhagen 1910.

1914. EKMAN, V. WALFRID: Der adiabatische Temperaturgradient im Meere. *Ann. d. Hydr. u. Mar. Met.*, Heft VI, 1914, Berlin 1914.

1922. EKMAN, V. W.: Dynamische Gesetze der Meeresströmungen. *Vorträge aus dem Gebiete der Hydro- und Aerodynamik*. Innsbruck 1922.

1923. EKMAN, V. W.: Über Horizontalzirkulation bei winderzeugten Meeresströmungen. *Arkiv för matematik, astronomi och fysik*, Band 17, No. 26. Stockholm 1923.

1927. EKMAN, V. WALFRID: Meeresströmungen. *Handbuch d. Physikalischen und Technischen Mechanik*, Band V, Lieferung 1. Leipzig 1927.

1928. EKMAN, V. WALFRID: Note on the Theoretical Courses of Ocean-Currents. *Journal du Conseil International pour l'Exploration de la Mer*, Vol. III, No. 1. Kjøbenhavn 1928.

1928. EKMAN, V. W.: A Survey of Some Theoretical Investigations on Ocean Currents. *Journal du Conseil International pour l'Exploration de la Mer*, Vol. III, No. 3. Copenhagen 1928.

1905. HELLAND-HANSEN, B.: Report on Hydrographical Investigations in the Faeroe-Shetland Channel and the Northern Part of the North Sea in 1902. *Report on Fishery and Hydrographical Investigations in the North Sea and Adjacent Waters*. Published by the Fishery Board for Scotland. Edinburgh 1905.

1907. HELLAND-HANSEN, BJØRN: Current Measurements in Norwegian Fjords, the Norwegian Sea and the North Sea in 1906. *Bergens Museums Aarbog* 1907, No. 15. Bergen 1907.

1911. HELLAND HANSEN, BJØRN: Neue Forschungen im Nördlichen Atlantischen Ozean. *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*. Berlin 1911.

1912. HELLAND-HANSEN, B.: Physical Oceanography. In *John Murray and Johan Hjort: The Depths of the Ocean*. London 1912.

1912. HELLAND-HANSEN, BJØRN: The Ocean Waters. I. *Internationale Revue der gesamten Hydrobiologie und Hydrographie*, Vol. V. Leipzig 1912.

1916. HELLAND-HANSEN, B.: Nogen hydrografiske metoder. *Forhandlinger ved de skandinaviske naturforskeres 16de møte i Kristiania*, 10.—15. juli 1916. Oslo 1918.

1909. HELLAND-HANSEN, BJØRN and NANSEN, FRIDTJOF: The Norwegian Sea. *Report on Norwegian Fishery and Marine Investigations*, Vol. II, No. 2. Kristiania (Oslo) 1909.

1917. HELLAND-HANSEN, B. und NANSEN, F.: Temperatur-Schwankungen des nordatlantischen Ozeans und in der Atmosphäre. *Videnskapsselskapets skrifter*, Kristiania 1917.

1920. HELLAND-HANSEN, B. and NANSEN, F.: Klimavekslinger og deres aarsaker. *Naturen*, Bergen 1920.

1920. HELLAND-HANSEN, B. and NANSEN, F.: Temperature Variations in the North Atlantic Ocean and in the Atmosphere. *Smithsonian Miscellaneous Collections*, Vol. 70, No. 4. Washington, 1920.

1926. HELLAND-HANSEN, B. and NANSEN, F.: The Eastern North Atlantic. *Geofysiske Publikasjoner*, Vol. IV, No. 2. Oslo 1926.

1929. HESSELBERG, TH.: Die Stabilitätsbeschleunigung im Meere und in der Atmosphäre. *Ann. d. Hydr. u. Mar. Met.* LVII Jahrg., Heft. IX. Berlin 1929.

1915. HESSELBERG, TH., und SVERDRUP, H. U.: Beitrag zur Berechnung der Druck- und Massenverteilung im Meere. *Bergens Museums Aarbok*. 1914—15, nr. 14. Bergen 1915.

1915. HESSELBERG, TH. und SVERDRUP, H. U.: Die Stabilitätsverhältnisse des Seewassers bei vertikalen Verschiebungen. *Bergens Museums Aarbok* 1914—1915. Bergen 1915.

1929. HESSELBERG, TH. und SVERDRUP, H. U.: Über die Genauigkeit der Berechnung der Druck- und Massenverteilung und der Stabilitätsverhältnisse im Meere. *Ann d. Hydr.*, LVII. Heft. III. Berlin 1929.

1913. JACOBSEN, J. P.: Beitrag zur Hydrographie der dänischen Gewässer. *Meddelelser fra Kommissionen for Havundersøgelser*, Serie: Hydrografi, Vol. II, No. 2. Copenhagen 1913.

1916. JACOBSEN, J. P.: Contribution to the Hydrography of the Atlantic. Researches from the M/S "Margrethe" 1913. *Meddelelser fra Kommissionen for Havundersøgelser,* Serie: Hydrografi, Vol. II. Copenhagen 1916.

1927. JABOBSEN, J. P.: Eine graphische Methode zur Bestimmung des Vermischungskoeffizienten im Meere. *Gerlands Beiträge zur Geophysik.* Bd. XVI, Heft 4. Leipzig 1927.

1898. KNUDSEN, MARTIN: Hydrografi. *Den danske Ingolf-Expedition.* Første Bind, 2. Kjøbenhavn 1898.

1911. KNUDSEN, MARTIN: Danish Hydrographical Investigations at the Faeroe Islands in the Spring of 1910. *Meddelelser fra Kommissionen for Havundersøgelser.* Serie: Hydrografi. Vol. II. Copenhagen 1911.

1923. KNUDSEN, MARTIN: Om Maaling af Lysets Nedtrængen i Havet. *Festskrift tillägnad Professor Otto Pettersson den 12. februari* 1923. Helsingfors 1923.

1907. KRÜMMEL, OTTO: Handbuch der Ozeanographie. Band I. Stuttgart 1907.

1911. KRÜMMEL, OTTO: Handbuch der Ozeanographie. Band II. Stuttgart 1911.

1909. KRÜSS, GERHARD und KRÜSS, HUGO: Kolorimetrie und Quantitative Spektralanalyse in ihrer Anwendung in der Chemie. Hamburg und Leipzig 1909.

1895. MURRAY, JOHN: A Summary of the Scientific Results obtained at the Sounding, Dredging, and Trawling Stations of H. M. S. Challenger. *Report on the Scientific Results of the Voyage of H. M. S. Challenger during the Years 1872—76.* Summary of the Scientific Results. Part I. London 1895.

1924. MÖLLER, LOTTE: Die Deviation bei Strommessungen im Meere. *Veröff. des Instituts für Meereskunde. Neue Folge. A. Geographish-naturwissenschaftliche Reihe.* Heft 13. Berlin 1924.

1926. MÖLLER, LOTTE: Methodisches zu den Vertikalschnitten längs 35.4° S. und 30° W. im Atlantischen Ozean. *Veröff. des Instituts für Meereskunde. Neue Folge. A. Geogr.-naturwis. Reihe.* Heft 15. Berlin 1926.

1901. NANSEN, F.: Some Oceanographical Results of the Expedition with the "Michael Sars" headed by Dr. Hjort in the Summer of 1900. *Nyt Magazin f. Naturvidenskab.* Kristiania 1901.

1902. NANSEN, FRIDTJOF: Oceanography of the North Polar Basin. *The Norwegian North Polar Expedition 1893—96. Scientific Results.* Vol. III, No. 9. Christiania 1902.

1912. NANSEN, FRIDTJOF: Das Bodenwasser und die Abkühlung des Meeres. *Internationale Revue der gesamten Hydrobiologie und Hydrographie.* Vol. V. Leipzig 1912.

1913. NANSEN, F.: The Waters of the North-Eastern North Atlantic. *Internationale Revue der gesamten Hydrobiologie und Hydrographie.* Hydrographisches Supplement zu Band IV. Leipzig 1913.

1907. NIELSEN, J. N.: Contribution to the Hydrography of the North-Eastern Part of the Atlantic Ocean. *Meddelelser fra Kommissionen for Havundersøgelser.* Serie: Hydrografi. Vol. I, No. 9. Copenhagen 1907.

1912. NIELSEN, J. N.: Hydrography of the Mediterranean and Adjacent Waters. *Report on the Danish Oceanographical Expeditions 1908—1910 to the Mediterranean and Adjacent Waters.* Vol. I. Copenhagen 1912.

1884. *Report on the Scientific Results of the Voyage of H. M. S. Challenger 1873—76.* Physics and Chemistry. Vol. I. Report on the Deep-Sea Temperature Observations of Ocean Waters etc. London 1884.

1912. *Report on the Danish Oceanographical Expeditions 1908—1910 to the Mediterranean and Adjacent Seas.* Vol. I: Introduction, Hydrography, Deposits of the Sea-Bottom. Kjøbenhavn 1912.

1914. *Report on the Work carried out by the S.S. "Scotia", 1913.* Ice Observation, Meteorology and Oceanography in the North Atlantic Ocean. London 1914.

1903. SANDSTRØM, J. W. und HELLAND-HANSEN, B.: Ueber die Berechnung von Meeresströmungen. *Report on Norwegian Fishery- and Marine-Investigations.* Vol. II, 1902, No. 4. Bergen 1903.

1915. SCHMIDT, WILHELM: Strahlung und Verdunstung an freien Wasserflächen; ein Beitrag zum Warmehaushalt des Weltmeeres und zum Wasserhaushalt der Erde. *Ann. d. Hydr. u. Mar. Met.*, Berlin 1915.

1917. SCHMIDT, WILHELM: Wirkungen der ungeordneten Bewegung im Wasser der Meere und Seen. *Ann. d. Hydr. u. Mar. Met.*, Berlin 1917.

1902. SCHOTT, GERHARD: Oceanographie und Maritime Meteorologie. *Wissenschaftliche Ergebnisse der Deutschen Tiefsee-Expedition auf dem Dampfer "Valdivia" 1898—1899.* Erster Band. Jena 1902.

1914. SCHOTT, GERHARD: Adiabatische Temperaturänderung in grossen Meerestiefen. *Ann. d. Hydr.* Juni 1914. Berlin 1914.

1926. SCHOTT, GERHARD: Geographie des Atlantischen Ozeans. Zweite Auflage. Hamburg 1926.

1914. SCHOTT, G., SCHULZ, B., PERLEWITZ, P.: Die Forschungsreise S.M.S. "Møwe" im Jahre 1911. *Aus dem Arkiv der Deutschen Seewarte,* XXXVII, 1914, No. 1. Hamburg 1914.

1923. SCHUMACHER, A.: Beobachtungen über die Deviation der Kompassnadel im Ekman-Strommesser. *Ann. d. Hydr. und marit. Met. 1923.* Berlin 1923.

1926. SVERDRUP, H. U.: Dynamic of Tides on the North Siberian Shelf. *Geofysiske Publikasjoner,* Vol. IV, No. 5. Oslo 1926.

1923. THORADE, H.: Schiffmagnetismus und Ekman—Merz—Strommesser. *Ann. d. Hydr. und Marit. Met. 1923.* Berlin 1923.

1927. THORADE, H.: Zur Kenntnis der Deviation bei Strommessungen. *Ann. d. Hydr. u. Marit. Met.*, Mai 1927. Berlin 1927.

1910. WALLÉN, AXEL: Vänerns Vattenståndsvariationer. *Meddelanden från Hydrografiska Byrån,* 1. Stockholm 1910.

1913. WALLÉN, A: Fleråriga Variationer hos Vattenståndet i Mälaren, Nederbörden i Uppsala och Lufttemperaturen i Stockholm. *Meddelanden från Hydrografiska Byrån, 4.* Stockholm 1913.

1916. WERENSKIOLD, WERNER: An Analysis of Current-Measurements in the Open Sea. *Forhandlinger ved de skandinaviske naturforskeres 16de møte i Kristiania 10.—15. juli 1916.* Oslo 1918.

1925. WERENSKIOLD, WERNER: Fysisk Geografi. Oslo 1925.

1920. WÜST, G.: Die Verdunstung auf dem Meere. *Veröffentlichungen des Instituts für Meereskunde. Neue Folge. A. Geographisch-naturwissenschaftliche Reihe,* Hefte 6. Berlin 1920.

1928. WÜST, GEORG: Der Ursprung der Atlantischen Tiefenwässer. *Sonderband der Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Hundertjahrfeier. 1828—1928.* Berlin 1928.

1929. WÜST, GEORG: Schichtung und Tiefenzirkulation des Pazifischen Ozeans auf Grund zweier Längsschnitte. *Veröff. d. Institut f. Meereskunde. Neue Folge. A. Geographisch-naturwissenschaftliche Reihe.* Berlin 1929.

PHYSICAL OCEANOGRAPHY

AND

METEOROLOGY

PART II

(TABLES AND PLATES)

Table I a. Surface-Observations.

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
IV. 9.	15.0	49 27	8 36	10·1	35·37	1
- „	22.0	29	9 14	9·35	·29	
- 10.	0.55	30	42	·6	·25	2
- „	3.30	31	10 15	·6	·34	
- „	7.15	32	49	10·4	·49	3
- „	13.25	38	11 35	·7	·50	4 A
- „	23.10	39	40	·6	·52	4 B
- 16.	14.35	51 24	9 27	8·4	34·66	5
- „	18.0	10	49	·6	35·23	
- „	20.0	50 57	10 8	9·05	·27	
- „	22.0	44	27	·3	·41	
- „	24.0	33	42	·9	·43	6
- 17.	2.0	25	58	10·05	·48	
- „	4.0	16	11 14	·3	·47	
- „	6.0	7	30	·4	·53	
- „	8.0	49 59	45	·55	·52	
- „	12.15	59	12 0	·8	·51	
- „	15.45	54	10	·6	·46	7
- 18.	2.0	49	8	·7	·50	
- „	4.0	36	11 59	·9		
- „	6.0	22	50	·7	·50	
- „	8.0	8	41	·9	·54	
- „	10.45	48 53	31	·95	·49	8
- „	13.0	36	21	·95	·55	
- „	15.0	19	11	·9	·53	
- „	17.0	4	2	11·0	·55	
- „	19.45	47 49	10 52	·0	·54	9
- „	22.0	32	41	·0	·52	
- „	24.0	16	31	·1	·57	
- 19.	2.0	0	21	·2	·70	
- „	4.0	46 46	11	·3	·55	
- „	6.0	28	0	·35	·55	
- „	8.0	12	9 50	·85	·64	

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
IV. 19.	10.0	45 56	9 40	11·7	35·64	
- „	17.0	26	20	12·3	·56	10
- 20.	6.10			11·6	·57	„
- 21.	8.50	44 54	36	·8	·61	
- „	13.40	25	18	·95	·61	11
- „	15.0	21	16	·9	·62	
- „	16.0	13	12	·8	·61	
- „	17.0	5	8	·8	·61	
- „	18.10	43 53	9	·9	·65	
- „	19.0	46	10	·9	·61	
- „	20.0	37	11	·4	·55	
- „	23.0	11	26	13·6	·47	12
- „	23.15	11	26	·15	·46	„
- „	24.0	7	21	12·6	·52	
- 22.	2.0	42 50	25	13·2	·16	
- „	4.0	33	23	·2	34·98	
- „	6.0	14	20	·5	35·08	
- „	8 25	41 51	10	·9	34·76	
- „	9.30			14·6	·02	
- „	10.30	31	6	15·2	·15	
- „	12.0	32	5	·2	33·84	13
- „	16.0	15	8 54	·4	34·50	
- „	18.30	8	9 6	·5	33·71	
- „	20.0	0	21	·6	32·79	
- „	22.0	40 56	28	·1		
- 23.	2.15	43	23	13·9	35·73	
- „	4.0	39	23	14·1	·80	
- „	6.15	20	23	13·65	·61	
- „	7.10	15	23	·9	·56	16
- „	8.0	13	23	·95	·59	
- „	10.0	39 55	26	14·2	·59	
- „	12.0	34	29	·5	·67	
- „	14.25	15	34	·65	·70	
- „	16.0	0	29	15·9	·73	
- „	18.0	38 41	33	13·6	·74	

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
IV. 23.	20.0	38 29	9 40	14·6	35·38	
- „	23.10	20	43	·8	·81	17
- 24.	2.0	4	35	·7	·64	
- „	4.0	37 48	27	·8	·99	
- „	6.0	32	19	15·1	·93	
- „	8.0	16	10	14·8	·87	
- „	10.30	36 57	8 46	·4	·90	
- „	12.0	54	25	15·8	·94	
- „	14.0	52	1	16·15	·95	
- „	16.0	50	7 44	17·0	36·14	
- „	18.0	48	21	16·9	·09	
- „	20.0	45	6 56	17·4	·28	
- „	22.0	38	39	16·9	35·81	
- „	24.0	25	26	17·2	·59	
- 25.	2.0	8	9	15·4	36·06	
- „	4.0	35 59	5 53	·5	35·99	
- 29.	12.30	35 56	5 43	17·0	36·12	18A
- „	14.30	56	43	16·6	·14	18B
- 30.	1.05	56	43	·6	·02	18C
- „	10.20	56	43	17·4	·17	18D
V. 2.	11.10	36 5	4 42	16·4	36·36	19A
- „	17.45	5	40	·9	·39	19B
- „	23.47	8	25	·7	·40	19C
- 3.	8.0			·3	·37	
- „	12.0	5	5 18	15·45	37·28	
- 4.	18.0			15·7	36·91	
- „	19.0	35 57	5 31	16·7	35·99	
- „	20.0	53	41	17·5	·90	
- „	21.0	51	50	·2	·90	

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
V. 4.	22.0	35 49	6 1	17·5	36·11	
- ,,	23.0	45	9	·5	·26	
- ,,	24.0	40	16	·15	·33	
- 5.	1.0	34	19	·1	·32	
- ,,	2.0	29	22	16·8	·32	
- ,,	4.10	25	25	·8	·27	20
- ,,	10.15	31	35	17·5	·36	21
- ,,	16.35	42	51	18·6	·37	22
- ,,	18.0	40	55	17·5		
- ,,	19.0	35	7 2	18·2	·37	
- ,,	20.15	32	7	17·9	·36	23
- 6.	18.30	34	33	18·05	·60	
- ,,	19.30	34	34	·05	·43	
- ,,	20.0	34	35	17·9	·39	24
- 7.	9.0	39	8 9	·9	·39	
- ,,	10.0	38	17	·75	·39	
- ,,	11.45	36	25	·8	·34	25A
- 8.	9.15	46	16	·8	·41	25B
- ,,	11.0	54	7	18·15	·40	
- ,,	12.0	36 2	7 59	·2	·38	
- ,,	13.0	9	49	·5	·42	
- ,,	14.0	13	43	·65	·45	
- ,,	15.0	18	36	·6	·47	
- ,,	16.0	23	29	·35	·42	
- ,,	17.0	28	22	17·8	·40	
- ,,	18.0	34	13	·65	·36	
- ,,	19.0	40	5	·5	·27	
- ,,	20.0	47	6 55	·4	·10	
- ,,	21.10	53	48	16·8	35·91	26
- ,,	22.0	51	49	·8	·95	
- ,,	23.0	43	54	17·0	36·25	
- ,,	24.0	35	58	·4	·38	
- 9.	1.30	31	7 1	·42	·37	27
- ,,	4.0	22	6	·65	·40	
- ,,	5.0	12	11	·6	·44	
- ,,	6.0	2	18	·35	·40	
- ,,	7.30	0	19	·5	·35	28
- ,,	16.0	35 20	48	18·1	·40	
- 10.	0.15	10	55	17·8	·36	29
- ,,	2.0	3	8 1	·65	·40	
- ,,	3.0	34 57	6	·5	·32	
- ,,	4.0	50	12	·4	·31	
- ,,	5.0	43	18	·3	·39	
- ,,	8.25	38	22	·4	·39	30
- ,,	11.0	26	21	·6	·40	
- ,,	12.0	17	20	·8	·44	
- ,,	13.0	6	21	·95	·52	

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
V. 10.	14.0	33 57	8 23	17·9	36·40	
- ,,	15.0	49	26	·95	·41	
- ,,	16.05	47	27	·7	·33	31
- ,,	18.0	42	28	·85	·38	
- ,,	19.0	30	31	·85	·26	
- ,,	20.20	27	32	·9	·21	32
- ,,	22.0	21	42	·8	·32	
- ,,	23.0	17	50	·6	·40	
- ,,	24.0	12	59	·4	·41	
- 11.	1.0	7	9 9	·7	·27	
- ,,	2.0	3	17	·4	·02	
- ,,	3.0	32 58	26	·7	·26	
- ,,	4.0	52	31	·6	·28	
- ,,	5.0	43	31	16·9	·21	
- ,,	6.0	35	31	15·7	·06	
- ,,	7.0	27	8 58	16·3	·17	
- ,,	8.0	19	53	15·85	·09	
- ,,	15.0	31 23	10 2	16·45	·13	
- ,,	16.30	17	6	·45	·25	
- ,,	19.0	17	6	·3	·06	33
- 12.	8.30	17	6	15·7		
- ,,	12.0	12	28	16·7	·31	
- ,,	13.0	6	34	·9	·26	
- ,,	14.0	0	43	17·4	·43	
- ,,	15.0	30 54	53	·45	·48	
- ,,	16.0	49	11 0	·4	·48	
- ,,	17.0	43	9	·3	·34	
- ,,	18.0	39	15	·4	·45	
- ,,	20.0	29	30	·5	·37	
- ,,	21.0	25	36	·4	·48	
- ,,	22.0	20	43	·6	·46	
- ,,	23.0	14	52	·5	·44	
- ,,	24.0	10	57	·6	·47	
- 13.	1.0	4	12 5	·55	·45	
- ,,	2.0	0	11	·6	·45	
- ,,	3.0	29 54	20	·5	·44	
- ,,	4.0	49	27	·7	·46	
- ,,	5.0	44	34	·5	·44	
- ,,	6.0	36	44	·8	·61	
- ,,	7.0	31	50	·8	·53	
- ,,	8.0	25	58	·7	·64	
- ,,	9.0	21	13 10	·9	·49	
- ,,	10.0	21	19	·95	·53	
- ,,	11.0	21	26	·9	·54	
- ,,	12.0	18	35	·6	·55	
- ,,	13.0	12	42	·7	·54	
- ,,	14.30	3	52	18·05	·62	

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
V. 13.	16.0	28 55	14 8	18·4	36·64	
- ,,	17.0	52	16	·1	·69	34
- 14.	10.0	21	50	·5	·62	
- ,,	11.0	13	58	·25	·61	
- ,,	12.0	10	15 8	·4	·55	
- 18.	7.0	28 2	15 13	18·5	36·52	
- ,,	8.0	27 55	9	·5	·55	
- ,,	9.20	44	2	·5	·52	
- ,,	10.0	39	14 59	·35	·26	
- ,,	11.0	32	55	·5	·11	
- ,,	13.0	27	52	·6	·37	35
- 19.	7.0	4	39	·75	·57	
- ,,	8.0	26 57	35	·8	·52	
- ,,	9.0	48	31	·15	·54	
- ,,	10.0	41	27	19·1		
- ,,	11.0	32	26	·3	·61	
- ,,	12.0	25	30	·3	·55	
- ,,	18.54	12	26	16·4	·20	36
- 20.	8.37	6	33	17·65		37
- ,,	11.40	3	36	19.2	·15	38
- ,,	18.26	3	15 0	·2	·48	39A
- 21.	15.0	11	12	·1		
- ,,	16.0	13	4	·05	·50	
- ,,	17.0	16	14 57	18·95	·55	
- ,,	18.0	19	48	19·05	·62	
- ,,	19.0	21	41	·05		
- ,,	20.0	24	34	18·85	·41	
- ,,	21.0	29	27	·4	·56	
- ,,	22.0	33	21	·5		
- ,,	23.0	37	15	19·0	·56	
- ,,	24.0	40	12	18·95	·56	
- 22.	1.0	45	6	·85	·72	
- ,,	2.0	48	9	·6	·65	
- ,,	3.0	53	4	·5	·59	
- ,,	4.0	58	0	·5	·55	
- ,,	5.0	27 4	13 54	·9	·61	
- ,,	6.0	9	49	·3	·29	
- ,,	7.0	14	43	·1	·35	
- ,,	8.0	19	39	17·7	·27	
- ,,	9.0	24	35	·9	·33	
- ,,	10.0	29	30	·9	·25	
- ,,	11.0	32	33	18·05	·28	
- ,,	12.0	35	33	·25	·33	
- ,,	13.0	40	29	·35	·28	
- ,,	14.0	46	24	·20	·17	

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
V. 22.	15.0	27 51	13 20	18·15	36·21	
- „	16.0	56	16	·35	·29	
- „	17.0	28 1	12	·30	·31	
- „	18.0	6	7	·45	·44	
- „	19.0	10	12	·55	·44	
- „	20.0	13	22	·4	·44	
- „	22.0	15	29	·4	·44	40
- 23.	5.0	9	34	·5	·50	

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
V. 23.	14.0	28 0	13 35	18·45	36·47	
- „	15.0	27 56	45	·55	·45	
- „	16.0	52	54	·55	·50	
- „	17.0	49	14 3	·6	·44	
- „	18.20	57	15	·5	·45	
- „	19.0	28 2	17	·5		
- 24.	3.0	2	17	·4	·44	
- „	7.0	27 58	14	·4	·44	

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Remarks
1910		° ′	° ′	°C.	‰	
V. 24.	8.0	27 59	14 23	18·5	36·47	
- „	9.0	28 0	35	·1	·49	
- „	10.0	3	45	·2	·50	
- „	11.0	5	52	·45	·67	
- „	12.0	7	15 2	·5	·73	
- „	13.0	8	11	·5	·73	
- „	14.0	9	17	·45		

Table I b. Surface-Observations and Meteorological Records.

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)	(0–6)	
V. 27.	5.0	27 54	15 18	18·3	36·65					
- „	6.0	47	25	·1	·58					
- „	7.0	50	30	·5						
- „	8.0	52	37	19·0	·68					
- „	9.0	51	47	18·7	·68					
- „	10.0	51	59	·7	·68					
- „	11.0	51	16 10	·6	·65					
- „	12.0	51	20	·3						
- „	13.0	55	30	·4						
- „	14.0	56	40	·75	·70					
- „	15.0	58	50	·9	·67					
- „	16.0	59	17 0	·9	·59					
- „	17.0	28 1	11	19·6	·68					
- „	18.0	2	18	·55	·72					
- „	19.0	6	23	·5	·68					
- „	20.0	11	30	·5	·64					
- „	21.0	16	37	18·7	·68					
- „	22.0	20	43	·8	·68					
- „	23.0	26	51	·8						
- „	24.0	29	58	19·0						
- 28.	1.0	30	18 6	18·55	·64					
- „	2.0	31	15	19·05						
- „	3.0	32	22	·1						

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)	(0–6)	
V. 28.	4.0	28 33	18 30	19·4						
- „	5.0	34	41	·35						
- „	6.0	35	50	·4						
- „	7.0	36	19 0	·0						
- „	10.20	37	8	·2	36·87					44
- „	14.0	37	8			*19.0*			NE^{b}N. 1-2	„
- „	17.30	41	46	·2						
- „	19.0	42	55	·1						
- 29.	8.0	37	20 14	·0	·83					
- „	9.0	38	23	·0	·76					
- „	10.0	39	32	18·8	·74					
- „	11.0	41	42	19·1	·82					
- „	12.0	43	53	·0	·77					
- „	13.0	45	21 1	·2	·83					
- „	14.0	47	10	·85	37·09					
- „	15.0	49	18	·9						
- „	16.0	52	27	·9	·05					
- „	17.0	54	37	·8	·03					
- „	18 35	56	45	·7	·00	*19.0*			E^{b}S 1-2	46
- „	22.0	56	48	·5	36·91					
- „	23.0	57	56	·4	37·06					
- „	24.0	58	22 6	·6	·05					
- 30.	1.0	59	15	·95	·04					

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
V. 30.	2.0	29 0	22 26	19·8	37·04					
- „	3.0	1	38	·8	·04					
- „	4.0	2	48	·85						
- „	21.30	28 50	59	·65	36·94					
- „	22.0	50	23 4	·7	37·03					
- „	23.0	51	12	·55	·08					
- „	24.0	51	21	·55	36·98					
- 31.	1.0	52	32	·2	·68					
- „	2.0	52	40	·3						
- „	3.0	53	52	·4						
- „	4.0	53	24 0	·2	36·85					
- „	5.0	54	11	·25	·76					
- „	22.0	39	9	20·55	·98					
- „	24.0	45	21	19·6	·76					
VI. 1.	1.0	51	33	·7	·74					
- „	2.0	55	40	20·05	·80					
- „	3.0	59	48	19·7	·76					
- „	4.0	29 2	56	·75	·64					
- „	5.0	6	25 6	20·5	·74					
- „	10.0	8	16			20·4	89			
- „	19.0	7	32			·3	88			
- 2.	8.30	2	30							49 C
- „	11.0	1	30			20·5		3—4	NNE. 1	„
- „	20.0	9	51	·4	·76					
- „	21.0	11	26 1	·3						
- „	22.0	13	11	·5	·82					
- „	23.0	15	22	·4	·89					
- „	24.0	17	32	·4	·94					
- 3.	1.0	19	42	·4	·80					
- „	2.0	21	51	·4						
- „	3.0	23	27 2	·4	·84					
- „	4.0	25	11	·35	·81					
- „	5.0	28	21	·6	·89					
- „	7.0	30	31	·45	·85					
- „	8.0	32	40	·55	37·02					
- „	9.0	34	51	·4	36·89					
- „	10.0	36	28 2	·3	·78					
- „	11.0	38	13	·4						
- „	12.0	41	25	·45	·80	·8	80	4—5	ENE. 3	
- „	13.0	43	35	·5						
- „	14.0	45	44	·5		·2	83	2—3	ENE. 3	
- „	15.0	47	54	·4						
- „	16.0	49	29 4	·3	·68	19·7	82	3—4	ENE. 3	
- „	17.0	51	14	·3						
- „	18.0	53	24	·25		·8	73	7—8	ENE. 3	
- „	19.0	55	33	·35						

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
VI. 3.	20.0	29 56	29 42	20·1	36·76	19·9	80	6—7	ENE. 3	
- „	21.0	58	54	·15						
- „	22.0	58	30 0	·2		20·2	78	5—6	ENE. 3	
- „	23.0	59	8	·0						
- „	24.0	30 1	26	·05	·57	19·5	77	6—7	E. 3	
- 4.	1.0	2	35	·25						
- „	2.0	4	47	·1	·58	20·0	76	8—9	E. 3	
- „	3.0	6	59	·0						
- „	4.0	7	31 8	·15	·60	19·6	78	8—9	E. 3	
- „	6.0	8	19	·25	·81	·5	77	9—10	E. 3	50
- „	7.0	„	„	·3						„
- „	8.0	„	„	·4	·81	·5	82	8—9	E. 3	„
- „	10.0	11	22	·35	·80	20·2	79	8—9	E. 3	
- „	11.0	20	33	·35						
- „	12.0	29	44	·6	·92	·9	71	3—4	E. 3	
- „	13.0	32	54	·95						
- „	14.0	35	32 5	21·1		21·2	67	2—3	E. 3	
- „	15.0	37	14	20·85						
- „	16.0	40	24	·55	·82	20·4	66	2—3	E. 2-3	
- „	17.0	42	34	·65						
- „	18.0	44	43	·25	·67	·8	70	1—2	E, 2-3	
- „	19.0	47	53	·4						
- „	20.0	49	33 2	·0	·62	·0	66	1—2	E. 2-3	
- „	21.0	52	13	·35						
- „	22.0	55	23	·5	·74	·3	77	1—2	E. 2	
- „	23.0	57	32	·55						
- „	24.0	31 0	42	·8	·82	·1	78	3-4	E. 2	
- 5.	1.0	3	52	·7						
- „	2.0	5	34 1	·5		·4	72	2—3	ESE. 3-4	
- „	3.0	8	11	·6						
- „	4.0	11	20	·6	·80	·0	67	2—3	ESE 2-3	
- „	5.0	14	30	·7						
- „	6.0	17	39	·65	·74	·2	73	6—7	EbS. 2-3	
- „	7.0	19	46	·4						
- „	8.0	22	58	·2	·63	21·1	68	5—6	EbS. 2-3	
- „	9.10	24	35 8	19·5						
- „	10.0	26	16	20·1	·52	·4	71	3—4	EbS. 2-3	
- „	11.0	28	25	·1						
- „	12.0	25	16	·15	·52	20·0	70	1—2	EbS. 2-3	
- „	13.0	21	9	·2						
- „	20.0	1)	1)	·3	·59	19·5	70	6—7	EbS. 2-3	
- „	21.0			·25						
- „	22.0			·2		·8	72	7—8	EbS. 2-3	
- „	23.0			·15						
- „	24.0			·15	·60	·8	76	5—6	EbS. 2-3	
- 6.	1.0			·35						

1) The ship was manoeuvring with tow-nets etc. from 5. June 13.10 to 6. June 9.30.

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910		° ′	° ′	°C	‰	°C.	%	(0—10)		(0—6)	
VI. 6.	2.0			20·45		19·4	81	4—5	EbS.	2-3	
- „	3.0			·5							
- „	4.0			·35	36·60	·3	79	5—6	EbS.	2-3	
- „	5.0			·5							
- „	6.0			·5		·5	77	8—9	EbS.	1-2	
- „	7.0			·6							
- „	8.0			·6	·65	20·1	77	5—6	EbS.	1-2	
- „	9.0			·7							
- „	10.0	31 20	34 56	·7		·5	84	6—7	E.	2	51
- „	11.0	„	„	·6							
- „	12.0	„	„	·6	·61	·4	85	6—7	ENE.	2	„
- „	14.10	„	„	·85		·8	82	7—8	SSE.	1-2	„
- „	15.0	„	„	·9							
- „	16.0	„	„	·75	·63	·0	78	7—8	SSE.	0-1	„
- „	17.0	„	„	·9		·7	77				„
- „	18.0	22	54	·9		·0	78	3—4	C		
- „	19.0	¹)	¹)	·9		19·8	72	4—5	NE.	1-2	
- „	20.0			·65	·64						
- „	21.0			·6							
- „	22.0			·8		·6	72	3—4	NE.	0-1	
- „	23.0			·75							
- „	24.0	24	47	·85	·72	·3	75	8—9	NNE.	1-2	
- 7.	2.0	24	47	·9		·8	76	8—9	NNE.	1	
- „	3.0	31	47	·5							
- „	4.0	40	48	·7	·72	·5	71	8—9	NNE.	1-2	
- „	5.0	50	49	·7							
- „	6.0	32 1	49	·5	·68	·5	75	8—9	NNE.	2	
- „	7.0	11	50	·4							
- „	8.0	19	50	·55	·49	·6	77	2—3	NNE.	2	
- „	9.0	30	51	·6							
- „	10.0	40	51	·7	·66	·6	76	1	NNE.	1	
- „	11.0	50	52	·9							
- „	12.0	59	52	·8	·66	·5	82	1	NNE.	1	
- „	13.0	33 6	45	·9							
- „	14.0	14	38	·8	·50	20·0	77	1	NNE.	1-2	
- „	15.0	22	31	21·05							
- „	16.0	29	25	20·9	·57	19·7	85	5—6	NNE.	2	
- „	17.30	41	14	·45							
- „	18.0	45	12	·45	·41	·7	80	2—3	NE.	2	
- „	19.0	53	5	·3							
- „	20.0	34 0	33 59	·5	·55	·2	73	2—3	NE.	2-3	
- „	21.0	8	52	·5							
- „	22.0	14	46	19.8	·41	·2	74	1	NE.	2	

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VI. 7.	23.0	34 22	33 38	19·6							
- „	24.0	27	33	·4	36·18	19·0	74	1	NE.	2	
- 8.	1.0	33	27	·15							
- „	2.0	40	21	·4	·26	18·5	74	1—2	NE.	2	
- „	3.0	47	15	·3							
- „	4.0	53	9	·3	·24	·4	75	2—3	NE.	2	
- „	6.0	57	5	·3	·30	·6	72	1—2	NE.	1-2	
- „	7.0	²)	²)	·3							
- „	8.0			·45	·34	·5	72	1	NE.	1-2	
- „	9.0			·6							
- „	10.0			·45		·8	78	2—3	NE.	1-2	
- „	11.0			·55							
- „	12.0	59	1	·65	·40	19·1	77	5—6	NE.	1-2	
- „	13.0			·85							
- „	14.0			·8	·44	·2	77	6—7	NE.	1	
- „	16.0			20·0	·41	·2	74	2—3	NE.	1-2	
- „	17.0			19·95							
- „	18.0			·85		18·8	71	1—2	NE.	1-2	
- „	19.0			·85							
- „	20.0			·7	·44	·9	66	1—2	NE.	1-2	
- „	21.0			·8							
- „	22.0			·85		·9	81	9—10	NE.	1-2	
- „	23.0			·7							
- „	24.0			·8	·39	·7	82	10	NE.	1-2	
- 9.	1.0			·5							
- „	2.0			·5		·8	88	7—8	NE.	1-2	
- „	3.0			·6							
- „	4.0			·5	·30	·2	96	9—10	NE.	1-2	
- „	8.0	35 7	32 30	·5	·33	19·3	83	2—3	NE.	1-2	53
- „	9.0	„	„	·55							„
- „	10.0	„	„	·6		·6	79	1	NE.	1-2	„
- „	11.0	„	„	·75							„
- „	12.0	„	„	·8	·35	·2	77	1	NE.	1-2	„
- „	13.0	„	„	·8							„
- „	14.0	7	30	·8	·29	·1	77	1—2	NE.	2	
- „	15.0	9	21	·7							
- „	16.0	11	12	·55	·18	18·9	80	2—3	NE.	2	
- „	17.0	13	3	·55							
- „	18.0	15	31 53	·5	·18	·9	84	3—4	NE.	2-3	
- „	19.0	17	44	·3							
- „	20.0	19	35	·2	·25	·8	86	5—6	NE.	2-3	
- „	21.0	21	27	·1							
- „	22.0	23	18	·1	·34	·8	86	1—2	NE.	2-3	

¹) Tow netting from 6. June 18.30 to 7. June 0.10 (Stat. 52).
²) Trawling and tow-netting from 8. June 6.10 to 9. June 7.45

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910		′	′	C.	‰	C.	%	(0–10)		(0–6)	
VI. 9.	23.0	35 25	31 9	19·2							
- „	24.0	27	1	·1	36·36	18·8	89	1	NE.	2-3	
- 10.	1.0	29	30 52	·15							
- „	2.0	31	44	·05	·40	17·9	85	2—3	NE.	3	
- „	3.0	33	36	·0							
- „	4.0	34	29	·2	·42	·4	74	4—5	NE.	3	
- „	5.0	36	20	·0							
- „	6.0	37	15	18·95	·40	·4	70	3—4	NNE.	3	
- „	7.0	39	14	·95							
- „	8.0	45	11	·6	·30	·9	74	6—7	NNE.	3	
- „	9.0	53	8	·7							
- „	10.0	36 0	5	·8	·21	·8	72	1—2	NNE.	3	
- „	11.0	6	1	·75							
- „	12.0	13	29 57	·6	·23	·9	73	0—1	NNE.	3	
- „	13.0	21	53	·6							
- „	14.20	24	52	·5	·21	18·2	71	1	NNE.	2	
- „	15.0	26	52	·35							
- „	16.0	33	51	·4	·23	·0	73	1	NEbE.	2	
- „	17.0	41	50	·6							
- „	18.0	49	48	·5	·21	·0	71	1	NEbE.	1	
- „	19.0	53	47	·6							
- „	20.0	[1]	[1]	·5	·21	17·8	62	0	C.		
- „	21.0			·3							
- „	22.0			·35		·4	74	1	NE.	1	
- „	23.0			·3							
- „	24.0			·3		·5	80	2	NE.	1	
- 11.	1.0			·15							
- „	2.0			·1		·8	80	1	ENE.	1	
- „	3.0			·1							
- „	4.0			·2		·2	81	1	E.	1	
- „	7.0	37 0	43	·35							
- „	8.0	2	42	·6	·20	19·1	74	2	C.		
- „	9.0	5	41	·75							
- „	10.0	6	41	19·4	·25						
- „	11.0	7	41	18·85	·25						57 A
- „	12.0	9	40	20·7	·28	18·4	75	0—1	C.		57 B
- „	13.0	11	39	·9							
- „	14.0	17	37	21·75	·27	·8	73	1	C.		57 C
- „	15.30	21	36	20·6							
- „	16.0	24	35	21·1		·7	83	0—1	C.		
- „	17.0	31	33	·4							
- „	19.0	33	29	20·45							
- „	20.0	35	31	18·7	·25	17·8	81	0—1	C.		
VI. 11.	21.0	[2]	[3]	19·6							
- „	22.0			·4		18·2	82	0	S.	0-1	
- „	23.0			·4							
- „	24.0	37 37	29 25	·0	36·25	17·8	82	0	S.	1	58
- 12.	1.0	„	„	·15							„
- „	2.0	„	„	·1		·7	80	2	SW.	1	„
- „	3.0	„	„	·0							„
- „	4.0	„	„	18·85	·25	·6	80	2—3	WSW.	1	„
- „	5.0	„	„	·55							„
- „	6.0	„	„	·6		·8	82	0—1	SW.	1	„
- „	7.0	„	„	·7							„
- „	8.0	„	„	·7		·8	80	1—2	SW.	1	„
- „	9.0	„	„	·8							„
- „	10.0	„	„	19·05		18·6	78	1—2	SW.	1	„
- „	11.0	„	„	·15							„
- „	12.0	„	„	·3	·26	·6	77	1—2	SW.	1	„
- „	13.0	„	„	·25							„
- „	15.25	„	„	·2	·18						„
- „	18.0	40	24	·0		19·4	76	1	SSW.	1	
- „	19.0	[3]	[3]	·0							
- „	20.0			18·8	·24	18·4	78	6—7	SSW.	2	
- „	21.0			·7							
- „	22.0			19·0		·4	76	1—2	SSW.	2	
- „	23.0			18·8							
- „	24.0			·95	·24	·1	85	9—10	SSW.	2	
- 13.	1.0			·75							
- „	2.0			·7		·4	83	3—4	SW.	2-3	
- „	3.0			·7							
- „	4.0			·65	·25	·6	86	4—5	SW.	3	
- „	5.0			·55							
- „	6.0	38	10	·65		·9	81	2—3	SW.	2-3	
- „	7.0	46	5	·4							
- „	8.0	52	0	·4		19·4	80	1—2	SW.	2-3	
- „	9.0	59	28 55	·2							
- „	10.0	38 7	50	·5		·0	80	2—3	SSW.	2-3	
- „	11.0	14	46	·5							
- „	12.0	20	42	·45		20·0	83	1—2	SSW.	2-3	
- „	13.0	27	39	·45							
- 17.	16.45	38 30	28 37	18·9	36·26	*19·6*	94		WSW.	3	59
- „	18.0	29	43	·75		·0	95	2—3	W.	3	
- „	19.0	29	52	19·0							

[1]) Tow-netting from 10. June 18.35 to 11. June 7.0.
[2]) Trawling from 20.0 to 24.0.
[3]) Tow-netting from 12. June 19.30 to 13. June 5.25.

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Wind Dir.	Wind Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VI. 17.	20.0	38 29	29 0	18·6		18·9	94	5—6	W.	3	
- „	21.0	29	10	·8							
- „	22.0	29	18	·8		·9	96	2—3	W.	3	
- „	23.0	29	27	·8							
- „	24.0	29	36	·7		19·0	93	2—3	W.	3	
- 18.	1.0	29	46	·6							
- „	2.0	29	56	·7		18·8	96	6—7	W.	3	
- „	3.0	29	30 6	·6							
- „	4.0	29	15	·55		·4	95	8—9	W.	3	
- „	5.0	28	24	·6							
- „	6.0	28	33	·5		·4	95	8—9	W.	3	
- „	7.0	28	38	·6							
- „	8.0	28	51	·8		·8	95	8—9	WSW.	3	
- „	9.0	28	31 1	·75							
- „	10.0	28	10	·7	36·26	16·2	100	7—8	W.	3	
- „	11.0	28	19	19·05							
- „	12.0	28	28	18·9		17·8	95	3—4	WSW.	3	
- „	13.0	28	36	·95							
- „	14.0	27	45	·9		18·4	93	2—3	W.	3	
- „	15.0	27	55	19·0							
- „	16.0	27	32 4	18·9	·25	·8	91	1—2	W.	3	
- „	17.0	26	11	·95							
- „	18.0	26	21	·8	·17	16·8	100		W.	2-3	R
- „	19.0	26	29	·65							
- „	20.0	25	37	·6	·21	18·4	86	2—3	WNW.	3	
- „	21.0	22	46	·6							
- „	22.0	19	54	·7		·2	97	5—6	WNW.	3	
- „	23.0	16	33 1	·6							
- „	24.0	13	9	·3	·21	·0	95	4—5	WNW.	3	
- 19.	1.0	10	16	·5							
- „	2.0	6	26	·8		17·0	94	10	NW.	3	
- „	3.0	3	34	19·0							
- „	4.0	0	43	18·9	·17	18·0	91	1	NW.	3	
- „	5.0	37 56	53	19·0							
- „	6.0	52	34 4	18·9	·38	·2	90	2—3	NWbN.	2-3	
- „	7.0	49	12	19·0							
- „	8.0	45	21	18·9		·1	90	6—7	NWbN.	2-3	
- „	9.0	41	31	19·0							
- „	10.0	37	42	·15		·4	86	1	NNW.	1-2	
- „	11.0	34	53	·2							
- „	12.0	30	35 6	·95		·8	84	1	N.	1	
- „	13.0	28	15	20·7							
- „	14.0	26	27	21·1		19·4	84	0—1	NW.	1	
- „	15.0	25	37	·1							
- „	16.0	24	47	20·8	·29	·6	83	1—2	NW.	1	
- „	17.0	23	57	·5							

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Wind Dir.	Wind Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VI. 19.	18.0	37 22	36 7	20·5		19·2	87	1—2	NNW.	1	
- „	19.0	21	18	·15							
- „	20.0	20	28	·1	36·29	18·9	86	2—3	NNW.	1	
- „	21.0	19	37	·0							
- „	22.0	18	50	·1	·29	·9	85	1	C		
- „	23.0	17	37 2	·2							
- „	24.0	16	12	·4		19·0	87	0	C		
- 20.	1.0	15	22	·35							
- „	2.0	13	34	·3		·4	89	1	WSW.	1	
- „	3.0	11	45	·0							
- „	4.0	10	56	·1	·27	·5	92	2—3	WSW.	1	
- „	6.0	9	38 5	19·4	·26	·4	89	1—2	WSW.	1	60
- „	7.0	„	„	·8		20·0	89		SW.	0-1	„
- „	8.0	„	„	·8	·25	·0	91	1	WSW.	1	„
- „	9.0	„	„	·95							„
- „	10.0	9	12	20·0	·34	19·8	94	1	SW.	1	
- „	11.0	8	23	·3							
- „	12.0	7	34	·2	·37	20·0	93	1	SW.	1	
- „	13.0	6	39	·6							
- „	15.0	3	39 0	·9							
- „	16.0	2	7	·95	·39	·2	95	1	SW.	1	
- „	17.0	1	17	·5							
- „	18.0	0	29	·4	·33	·2	96	1	SbW.	1	
- „	19.0	36 59	39	·3							
- „	20.0	58	51	·3	·33	·2	100	3—4	SbW.	1	
- „	21.0	58	51	·15							
- „	22.0	58	52	·2		·0	100	1—2	SSW.	1.	
- „	23.0	57	53	·2							
- „	24.0	57	54	·2	·33	19·9	89	4—5	SSW.	1	
- 21.	1.0	57	55	·15							
- „	2.0	57	56	·1	·31	20·0	87	1	SbE.	1	
- „	3.0	57	57	·1							
- „	4.0	57	58	·1	·33	19·8	91	2	S.	1	
- „	5.0	57	59	·1							
- „	7.0	57	59	·15		20·1	87	2—3	S.	1	
- „	8.0	57	40 0	·1	·37	19·9	89	2—3	S.	1	
- „	9.0	56	11	·4							
- „	10.0	55	21	·65	·41	20·4	86	1—2	S.	1	
- „	11.0	54	32	·45							
- „	12.0	52	46	·7	·44	·6	85	1	S.	1-2	
- „	13.0	50	54	·85							
- „	14.0	47	41 5	21·05	·41	·8	85	1—2	S.	1-2	
- „	15.0	44	15	·2							
- „	16.0	41	26	·25	·43	·9	84	1	SW.	1-2	
- „	17.0	38	36	·15							
- „	18.0	35	46	·35	·39	21.1	85	1	SW.	2	

Date. Hour. (Ship's Time)	Position Lat. N	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
VI. 21. 19.0	36 33	41 56	21·2						
- „ 20.0	31	42 6	·3	36·42	21·0	85	3—4	SW. 2	
- „ 21.0	29	17	·1						
- „ 22.0	27	27	20·95	·45	·0	86	2—3	SW. 1	
- „ 23.0	24	37	·5						
- „ 24.0	22	47	·5	·42	·0	83	9—10	SWbW. 1-2	
- 22. 1.0	20	55	·8						
- „ 2.0	17	43 8	·2	·46	20·1	92	9—10	SW. 2	
- „ 3.0	14	18	21·2						
- „ 4.0	12	28	·4	·42	18·8	93	10	SW. 2	R
- „ 5.0	10	38	·4						
- „ 6.0	8	47	·6	·42	21·2	88	10	WSW. 1	
- „ 7.0	6	55	·55						
- „ 8.0	5	58	·65	·44	·0	91	8	WSW. 1	
- „ 10.0	„	„	22·2	·45	·0	93	6	SW. 1	63
- „ 12.0	„	„	·45	·45	·6	85	3—4	SW. 1	„
- „ 16.0	„	„	·4	·44	22·0	81	2—3	SW. 1	„
- „ 17.0	„	„	·35						„
- „ 18.30	„	„	·3	·46	·0	83	1	WSW. 1	„
- „ 19.10	„	„	·25						„
- „ 20.0	„	„	·0	·45	21·6	86	2	C.	„
- „ 23.0	„	„	·1		·4	88	4—5	C.	„
- „ 24.0	„	„	·1	·45	·3	89		C.	„
- 23. 2.0	4	44 1	21·9	·46	·6	87	2	W. 1	
- „ 3.0	2	10	·85						
- „ 4.0	0	17	·85	·46	·4	88	1—2	W. 0-1	
- „ 5.0	35 58	25	·8						
- „ 6.0	56	33	·8	·43	·6	85	4—5	W. 1	
- „ 7.0	54	41	22·05						
- „ 8.0	52	49	·0	·46	·9	87	4—5	W. 1	
- „ 9.0	50	58	·0						
- „ 10.0	47	45 7	·2	·45	22·0	87	3—4	W. 1-2	
- „ 11.0	45	16	·4						
- „ 12.0	43	24	·4	·46	·4	83	1—2	W. 1	
- „ 13.0	41	33	·2						
- „ 14.0	39	40	·5	·43	·5	83	3—4	WSW. 2	
- „ 15.0	37	48	·3						
- „ 16.0	35	56	·3	·46	·6	81	4—5	SWbW. 2	
- „ 17.0	33	46 3	·6						
- „ 18.0	31	12	·4	·43	·4	85	3—4	SWbW. 2	
- „ 19.0	28	21	·3						
- „ 20.0	24	30	·4	·43	·3	82	2—3	SW. 2.	
- „ 21.0	20	39	·1						
- „ 22.0	15	48	·4	·43	·0	85	1—2	SW. 2	

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.		°C.	%	(0—10)	(0—6)	
VI. 23. 23.0	35 11	46 57	22·5						
- „ 24.0	7	47 6	·5	36·67	22·0	85	4—5	SW. 2	
- 24. 1.0	2	16	·7						
- „ 2.0	34 58	25	·6	·66	·0	85	3—4	SW. 2	
- „ 3.0	54	33	·6						
- „ 4.0	50	41	·5	·59	21·8	86	5—6	SW. 2	
- „ 5.0	45	50	·6						
- „ 6.0	44	52	·4	·59	22·2	87	3	SW. 1	
- „ 7.0	[1]	[1]	·5						
- „ 8.0			·55	·57					
- „ 9.0			·8						
- „ 10.0			·8		·6	81	2—3	SW. 1-2	
- „ 11.0			·85						
- „ 12.0	47	52	·8	·58	·7	82	1	SWbW. 1-2	
- „ 13.0			·8						
- „ 14.0			·75	·61	·8	84	1	SSW. 2	
- „ 15.0			·9						
- „ 16.0			·95	·42	23·0	84	1—2	SW. 2	
- „ 17.0	48	52	·95						64
- „ 18.0	„	„	·8	·59	22·8	87	2	SW. 1	„
- „ 18.30	„	„			*22·5*	86	3	SW. 2	„
- „ 19.0	„	„	·8						„
- „ 20.0	„	„	·8	·58	·6	88	2—3	SW. 1	„
- „ 21.0	50	53	·65						
- „ 22.0	57	55	·4	·44	·4	89	2	SW. 1-2	
- „ 23.0	35 6	57	·5						
- „ 24.0	14	59	·4	·42	·4	90	4—5	SW. 1-2	
- 25. 1.0	22	48 1	·4						
- „ 2.0	31	3	·2		·2	92	2—3	SW. 1-2	
- „ 3.0	38	5	21·9						
- „ 4.0	46	7	·9	·37	·0	90	1—2	SW. 1	
- „ 5.0	54	9	·8						
- „ 6.0	36 2	11	·9	·40	·1	91	3—4	SWbW. 2	
- „ 7.0	11	13	·8						
- „ 8.0	20	15	·8	·42	·4	91	2—3	SWbW. 2	
- „ 9.0	31	17	22·05						
- „ 10.0	41	19	21·4	·47	·2	88	1—2	SWbW. 2-3	
- „ 11.0	51	21	·7						
- „ 12.0	59	23	22·0	·41	·2	90	1—2	SWbW. 2-3	
- „ 13.0	37 6	27	·1						
- „ 14.25	12	30	21·9	·43	·0	94	0—1	SWbW. 2-3	65
- „ 15.0	„	„	·9						„
- „ 16.0	„	„	·8	·37	23·4	87	0	SWbW. 2-3	„
- „ 17.0	„	„			*22·0*	92		SW. 2-3	„

[1] Tow-netting from 6.30 to 17.0.

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
VI. 25. 18.0	37 18	48 33	21·55	36·38	22·1	93	1—2	SWbW. 2-3	
- „ 19.0	25	36	·4						
- „ 20.0	32	39	·3	·37	21·8	94	2	SWbW. 2-3	
- „ 21.0	38	42	·5						
- „ 22.0	45	45	·4	·42	22·0	92	1—2	SWbW. 2-3	
- „ 23.0	52	49	·7						
- „ 24.0	59	52	·7	·42	·2	90	5	SWbW. 3	
- 26. 1.0	38 6	56	·7						
- „ 2.0	15	49 0	·4	·26	21·8	93	7—8	SWbW. 3	
- „ 3.0	22	3	·5						
- „ 4.0	29	6	·5	·19	22·0	94	2—3	SWbW. 3	
- „ 5.0	36	9	·8						
- „ 6.0	44	13	·9	·17	·0	94	2—3	SWbS. 2-3	
- „ 7.0	51	17	·8						
- „ 8.0	58	21	20·6	35·74	·0	92	6—7	SWbS. 2-3	
- „ 9.0	39 5	25	·1						
- „ 10.0	12	29	·05	·24	21·4	95	7—8	SWbS. 2-3	
- „ 11.0	18	33	19·7						
- „ 12.0	24	37	·6	34·50	20·9	95	9—10	SW. 2-3	R
- „ 16.0	30	42	·9	·70	·8	95	9	SW. 3-4	R
- „ 17.0	„	„	·8						
- „ 18.0	„	„	·75	·51	19·4	98	9	W. 2-3	R
- „ 19.0	„	„	·8						66
- „ 20.0	„	„	·8	·58	20·0	98	10	W. 2	„
- „ 21.20	„	„	·9						„
- „ 22.0	„	„	·85	·57	·2	98	10	SW. 1-2	„
- „ 23.0	„	„	·8						„
- „ 24.0	„	„	·8	·60	·2	98	9—10	SSW. 2	„
- 27. 1.0	31	43	20·0						
- „ 2.0	35	48	·0	·69	19·8	98	10	SSW. 1-2	R
- „ 3.0	40	54	·1						
- „ 4.0	44	59	·0	35·44	·8	93	9	SSW. 1	
- „ 5.0	49	50 5	19·85						
- „ 6.0	55	12	·8	·44	20·0	96	7—8	SW. 1	
- „ 8.0	40 5	24	·95	·43	·7	93	6—7	SW. 1	
- „ 9.0	11	31	20·9						
- „ 10.20	15	37	·6	36·03	21·4	89	10	S. 2.	67
- „ 11.0	17	39	·6						
- „ 12.0	17	39	21·7	·11	·0	89	7—8	S. 3-4	
- „ 13.0			·65						
- „ 15.0			·7		·6	87	9—10	S. 4	
- „ 18.40								SWbS. 5	
- „ 20.0			·7	·18	20·9	79	7—8	SW. 5	67 A
- „ 20.30								SW. 5-6	

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	′	C.	‰	°C.	%	(0—10)	(0—6)	
VI. 27. 22.0			21·7						
- 28. 4.0			·6	36·22	19·8	81	7—8	W. 3-4	
- „ 5.0	39 20	50 50	·2						68
- „ 6.0	„	„	·0	·17	·4	82	8—9	WbN. 2-3	„
- „ 7.0	„	„	·3						„
- „ 8.0	„	„	·2	·15	·6	77	2—3	W. 2-3	„
- „ 9.0	„	„	·35						„
- „ 10.15	„	„	·5	·26	.6	79	3—4	WNW. 2	„
- „ 12.0	34	58	·55	·19	·6	68	3—4	WNW. 3	
- „ 13.0	42	51 2	·6						
- „ 14.0	53	2	·4	·13	·4	70	2—3	WNW. 3	
- „ 15.0	58	2	·5						
- „ 16.0	40 6	2	·4	·15	·0	72	2	WNW. 3	
- „ 18.0	21	2	·45	·17	·0	72	2	NW. 2	
- „ 19.0	28	3	20·95						
- „ 20.0	35	3	·7	35·90	·0	74	2	NW. 2	
- „ 21.0	43	3	·8	36·03					
- „ 22.0	51	3	21·0	·10	18·0	81	2—3	NWbN. 2	
- „ 23.0	59	3	19·35	35·46					
- „ 24.0	41 6	4	·2	·35	17·4	82	0—1	NWbN. 2	
- 29. 1.0	14	4	18·5	·35					
- „ 2.0	23	4	·85	·54	·6	86	1—2	NWbN. 1	
- „ 3.0	31	4	·3	·68					
- „ 4.0	39	4	17·55	·50	18·0	82	1	SW. 1	69
- „ 5.40	„	„	·15						„
- „ 6.0	„	„	·15	·40	·4	91	0	SW. 1	„
- „ 7.0	„	„	·1						„
- „ 8.0	„	„			*19·5*	88	0—1	SW. 1	„
- „ 9.0	[1]	[1]	·45	·37					
- „ 10.0			·4	·29	·8	88	1	WSW. 1	
- „ 11.0			16·7	34·59					
- „ 12.0	48	7	·2	·33	21.8	83	1	S. 1	
- „ 13.0	58	7	13.8	33·07					
- „ 14.0	42 8	7	12·95	32·51	16·4	98	2—3	S. 1	
- „ 15.0	17	8	·7	·45					
- „ 16.0	26	8	·2	·40	·4	89	2—3	S. 1	
- „ 17.0	35	8	·2	·39					
- „ 18.0	44	8	·25	·32	15·4	94	6—7	S. 1-2	
- „ 19.0	53	9	11·8	·32					
- „ 20.0	43 2	9	·7	·38	14·6	96	7—8	SSE. 2	
- „ 21.0	9	9	12·0	·49					
- „ 22.0	14	7	·2	·64	15·0	98	10	SSE. 3	
- „ 23.0			·1	·58					
- „ 24.0			·1	·68	14.6	98	3—4	S. 3-4	

[1] Tow-netting from 8.0 to 12.0.

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0–10)		(0–6)	
VI. 30. 1.0			12·0	32·64						
- „ 2.0	42 59	51 15	11·9	·45	13·8	[100]	2—3	S.	2	70
- „ 3.0	„	„	·9							„
- „ 4.0	„	„	·9	·57	·8	[100]	7—8	S.	2-3	„
- „ 5.0	„	„	·95	·64						„ R
- „ 6.0	„	„	12·1	·69	14·0	[100]		SSW.	1-2	„ F
- „ 7.0	¹)	¹)	·0	·61						
- „ 8.0			·05	·54	·0	[100]	8—9	SSW.	2-3	
- „ 9.0			11·9	·45						
- „ 10.0			12·0	·43	·8	98	7—8	SSW.	2	
- „ 11.30			·05	·45						
- „ 12.0	57	18	·2	·42	15·0	98	5—6	SSW.	2	
- „ 13.0			·2	·42						
- „ 14.0			·35	·47	·0	100	3—4	SSW.	2	
- „ 15.0			·4	·55						
- „ 16.0	43 6	18	·45	·71	·8	100		SSW.	2	F
- „ 17.0	12	17	·25	·62						
- „ 18.0	18	17	·2	·59	14·8	100		SSW.	2	71, F
- „ 19.0	„	„	·2	·58						„
- „ 20.0	„	„	·0	·58	13·8	94	1—2	SSW.	1	„
- „ 21.0	„	„	·0	·61						„
- „ 22.0	„	„	·2	·61	·4	98	1—2	SSW.	1	„
- „ 23.0	28	17	·15	·59						
- „ 24.0	38	17	·0	·52	·2	98	1—2	SSW.	1	
VII. 1. 1.0	48	16	11·5	·56						
- „ 2.0	59	16	·65		·2	98	1	SW.	1	
- „ 3.0	44 11	16	·65	·33						
- „ 4.0	22	15	10·95	·21	12·4	100	5—6	SW.	1	
- „ 5.10	35	15	·7	·20						72
- „ 6.0	„	„	·55	·20	·6	99	6—7	SSW.	1	„
- „ 6.30	„	„			·9	99		SW.	1	„
- „ 7.0	„	„	·7	·20						„
- „ 9.0	„	„	·65	·25						„
- „ 10.0	„	„	·8	·27	·6	100	1—2	SbW.	1	„
- „ 11.0	36	22	·7	·27						
- „ 12.0	38	41	·65	·30	14·8	94	9—10	SbW.	1	
- „ 13.0	46	39	·6	·30						
- „ 14.15	45 0	36	·1	·25	14·6	90	2—3	SbW.	1	
- „ 15.20	11	34	9·75	·27						
- „ 16.0	18	33	·7	·30	·6	90		S.	1	F
- „ 17.0	27	31	·3	·26						
- „ 18.0	35	30	·1	·27	12·0	98	9—10	SW.	1	
- „ 19.0	45	28	·3	·26						
- „ 20.0	53	26	8·9	·28	10·8	99		SW.	1	F

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0–10)		(0–6)	
VII. 1. 21.0	45 58	51 25	8·45	32·07						73
- „ 22.0	59	26	·4	·19	10·0	100		C.		F
- „ 23.0	46 4	29	·7	·21						
- „ 24.0	6	31	·4	·36	9·2	[100]		W.	1	F
- 2 1·30	9	33	·3	·34						
- „ 2.0	11	35	·15	·32	8·4	[100]		W.	1	F
- „ 3.0	15	38	·1	·37						
- „ 4·0	18	40	·1	·29	·1	[100]		W.	1	F
- „ 5·0	23	44	7·5	·27						
- „ 6·0	24	45	8·1	·27	·2	100		W.	1	F
- „ 7.0	24	45	7·9	·29						
- „ 8.0	25	46	·5	·32	·0	100		W.	1	F
- „ 9.0	25	46	·9	·34						
- „ 10.0	32	51	8·05	·35	·8	[100]		W.	1	F
- „ 11.0	39	55	7·85	·35						
- „ 12.15	50	52 3	·4	·35	·2	100		WNW.	2	
- „ 13.0	53	4	·45	·35	·0	100		WNW.		
- „ 14.0	47 1	8	·5	·33	·0	100	5—6	WNW.	2	
- „ 15.0	9	11	·4	·28						
- „ 16.0	17	15	·45	·29	·4	98	6—7	W.	2	
- „ 17.0	23	18	·3	·27						
- „ 18.10	25	20	·2	·25	7·2	[100]	10	W.	1	74 R
- „ 19.0	26	25	·25	·21						
- „ 20.0	26	29	·5	·17	·8	95	10	NE.	1	R
- „ 21.0	32	32	·6	·14	·6	[100]		NE.	1-2	F
- „ 22.0	34	33	·7		·7	100	10	NE.	1	
- „ 23.0	„	„	·65				10	NE.	1-2	
- „ 24.0	„	„	·6		·8	100	10	NE.	1	
- 3. 2.35²)	„	39	8·0							
VII. 8. 12.0	47 35	52 37	8·45	32·10			1—2	WSW.	2-3	
- „ .50	34	31	9·0	·07						
- „ .55			8·55	·04						
- „ 13.0	34	29	·0	·08						
- „ .10			·35	·03						
- „ .15			·3	·07						
- „ .20			·25	·03						
- „ .25			·15	·03						
- „ .30	33	23	·1	·05						
- „ .35			·1	·04						
- „ .40			·2	·03						
- „ .45			·1	·07						
- „ .50			7·9	·04						

¹) Tow-netting from 6.0 to 15.0. ²) At St. John's (New Foundland).

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)		(0–6)	
VII. 8.	13.55			7·6	32·06						
- „	14.0	47 32	52 18	·7	·07						
- „	.05			·65	·09						
- „	.10			·55	·08						
- „	.15			·55	·09						
- „	.20¹)	32	14	·35	·09						
- „	.25			·3	·08						
- „	.30			·3	·09						
- „	.35			·25	·08						
- „	.40			·25	·08						
- „	.45			·3	·08						
- „	.50			·4	·08						
- „	.55			·4	·09						
- „	15.0	32	10	·95	·09						
- „	.05			·65	·08						
- „	.10			·75	·09						
- „	16.0	32	51 53	·5	·22	10·2	100	5	SW.	3	
- „	17.0	32	42	·2	·29						
- „	18.0	31	29	·1	·34	9·8	100		SW.	3	F
- „	19.0	30	16	·25	·34						
- „	20.0	30	4	6·8	·40	8·8	100		SW.	2-3	F
- „	21.0	29	50 50	·6							
- „	22.0	28	36	·6	·38	·4	[100]	7–8	SW.	2-3	
- „	23.0	27	26	·35	·40						
- „	24.0	26	17	·5	·42	·2	[100]	10	SW.	2-3	
- 9.	1.0	25	5	·6	·40						
- „	2.0	25	49 56	·45	·38	·0	98	10	SW.	3	R
- „	3.0	24	43	·5	·29						
- „	4.0	23	31	·3	·32	·0	[100]	10	SW.	2	R
- „	5.0	22	18	·5	·39						
- „	6.0	22	16	·3	·39	·6	[100]	10	WNW.	1-2	75, R
- „	7.0	22	13	·3							
- „	8.0	21	4	·5	·39	·1	[100]	8 9	W.	2	
- „	9.0	20	48 49	·45	·16						
- „	10.0	19	36	·0	·40	·2	98		W.	2	F
- „	11.0	18	24	5·85	·44						
- „	12.0	17	12	·2	·42	·0	98		W.	2	F
- „	13.0	16	0	·1	·41						
- „	14.0	15	47 45	·5	·47	6·8	[100]		WSW	2-3	F
- „	15.0	14	35	·95	·63						
- „	16.15	13	18	·4	·89	·8	100		C.		F
- „	17.0	12	9	·85	·89						
- „	18.0	11	6	·9	·89	·6	[100]		SW.	1	76, F
- „	19.0	„	„	·9	·87						„

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)		(0–6)	
VII. 9.	20.0	47 11	47 6	5·85	32·88	6·2	[100]		C.		76. F
- „	21.0	11	46 58	·5	·96						
- „	22.0	12	48	6·6	33·18	·4	97		C.		F
- „	23.0	12	41	·2	·21						
- „	24.0	12	36	5·75	·12	·2	100		C.		F
- 10.	1.0	13	31	6·3	·06						
- „	2.0	13	31	·3	·07	·9	[100]		C.		F
- „	3.0	13	31	·2	·10						
- „	4.0	13	31	·3	·07	·8	[100]		C.		F
- „	5.0	13	26	7·5	·16						
- „	6.0	13	21	·0	·02	7·2	[100]		S.	1	F
- „	7.0	14	12	6·5	32·97						
- „	8.0	14	1	·5	·95	·6	[100]		C.		F
- „	9.0	15	45 50	7·2	33·03						
- „	10.0	15	39	·45	·10	8·2	[100]		SSE.	0-1	F
- „	11.0	16	26	8·05	·17						
- „	12.0	17	16	·2	·18	·0	[100]		SSE.	0-1	F
- „	13.0	18	4	·3	·24						
- „	14.10	18	44 54	·1	·21	11·0	100		C.		77, F
- „	15.0	„	„	·45	·23						„
- „	16.0	18	49	9·5	·22	10·8	100		C.		F
- „	17.0	17	40	·3	·22						
- „	18.0	17	32	·4	·27	·4	100		C.		F
- „	19.0	16	22	·0	·29						
- „	20.0	16	17	·2	·30	·0	100		C.		79, F
- „	21.0	„	„	8·9		9·6			WSW.	0-1	„ F
- „	22.0	18	8	·35	·25	·3	100		C.		F
- „	23.0	20	43 59	·8	·39						
- „	24.0	23	51	·55	·42	·4	[100]	10	WSW.	0-1	
- 11.	1.0	26	41	·5	·47						
- „	2.0	29	31	7·5	·68	·8	98	5	WSW.	1	
- „	3.0	31	22	·8	·52						
- „	4.0	33	14	11·4	·86	10·2	98	4	WSW.	2	
- „	5.0	34	11	·8	34·24						80
- „	6.0	„	„	·8	·24	·1	96	4–5	WNW.	2	„
- „	7.0	„	„	·8							„
- „	8.0	„	„	·7		9·2	[100]		WNW.	2	F
- „	9.0	„	„	13·1	·19						
- „	10.0	„	„	·6	·16	·0	[100]		NW.	2	F
- „	11.0	„	„	11·7	·13						
- „	12.0	„	„	·55	33·99	·0	100	10	NW.	3	
- „	13.0	²)	²)	·6	·87						
- „	14.0			·65		·6	96	10	NWbN.	2-3	
- „	15.30			·7							

¹) At an ice-berg. ²) Tow-netting from 12 to 18 o'clock.

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0 10)		(0—6)	
VII. 11. 16.0			11.75	33.86	9.9	98	10	NWbN.	2-3	
- ,, 18.0	47 40	43 0	·6	·92	12.0	93	10	NNE.	2	
- ,, 20.0	42	42 46	·6	·59	11.9	95	9—10	NNE.	2	
- ,, 21.0	44	32	·45	·49						
- ,, 22.0	46	17	·4	·53	·8	93	10	NNE.	2	
- ,, 23.0	48	3	12.3							
- ,, 24.0	50	41 50	15.8	35.11	12.0	100	10	NNE.	2-3	
- 12. 1.0	52	37	·85	·52						
- ,, 2.0	54	24	16.35	·89	13.7	90	10	NE.	2-3	
- ,, 3.0	56	10	·3	·95						
- ,, 4.0	57	40 59	·3	·97	·4	89	9—10	NNE.	2-3	
- ,, 5.0	59	45	·1							
- ,, 6.0	48 0	31	·4	·67	·4	91	8	NE.	1-2	
- ,, 7.0	1	17	14.65							
- ,, 8.0	2	5	·5	·32	·0	89	4	NbE.	1	
- ,, 10.0	2	39 55	·8	·53	·1	92	10	C.		81
- ,, 11.0	,,	,,	15.2							,,
- ,, 12.0	,,	,,	16.0	·47	15.9	82	7—8	W.	1	
- ,, 13.0	1)	1)	15.6							
- ,, 14.0			16.0	·51	·1	91	1	WSW.	1	
- ,, 15.0			·5							
- ,, 16.0			15.6	·42	·2	90	1	WSW.	1	
- ,, 17.0			·15							
- ,, 18.0			·1	·37	·4	88	4	SW.	1	
- ,, 19.10	1	46	·0							81 A
- ,, 20.0	,,	,,	·1	·40	·4	86	8—9	WSW.	1-2	,,
- ,, 21.0	,,	,,	14.9	·39						,,
- ,, 22.0	3	34	13.8	·25	14.8	86	7—8	SSW.	2	
- ,, 23.0	5	22	·6	·13						
- ,, 24.0	7	9	·8	·01	·7	90	10	SSW.	2-3	
- 13. 1.0	9	38 56	·8							
- ,, 2.0	11	44	14.6	·27	15.0	90	10	SSW.	2-3	
- ,, 3.0	12	35	·4							
- ,, 4.0	14	19	·8	34.95	·2	94	10	WSW.	2-3	
- ,, 5.0	15	10	15.7	35.25						
- ,, 6.0	17	37 54	16.1	·61	16.0	94	10	SWbS.	2-3	
- ,, 7.0	18	42	15.6	·22						
- ,, 8.0	20	29	·4	·21	15.6	98	10	SWbS.	3	
- ,, 9.0	21	16	·3							
- ,, 10.0	22	3	·4	·12	·8	100	10	SW.	3	R
- ,, 11.0	23	36 52	·4							
- ,, 12.0	2)	2)	·4		16.6	98	10	WSW.	3	
- ,, 13.0			·5							
- ,, 14.15			·4	·09	15.4	88	9—10	WbN.	3	

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir.	Atmosphere Wind Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0 10)		(0—6)	
VII 13. 15.0			15.4							
- ,, 21.0	48 26	37 0	·4	35.28						82
- ,, 22.0	,,	,,	·2	·26	12.8	91	10	WbN.	3	,,
- ,, 23.0	,,	,,	·2		*13.0*	91	9	W.	3	,, R
- ,, 24.0	26	36 59	·0	·24	·0	89	10	WbN.	3	
- 14. 1.0	26	49	·1	·15						
- ,, 2.0	26	37	14.9	·10	12.4	88	4—5	WNW.	3	
- ,, 3.0	26	26	15.0	·00						
- ,, 4.0	26	15	14.0	·03	·7	86	5—6	WNW.	3	
- ,, 5.0	26	3	15.1							
- ,, 6.0	26	35 52	14.8	·07	·4	87	5—6	NWbN.	3	
- ,, 7.0	27	40	15.7							
- ,, 8.0	27	28	16.2	·75	13.6	87	7—8	WNW.	2-3	
- ,, 9.20	27	12	·4	·71						
- ,, 10.0	27	4	·6	·75	14.6	81	4—5	WNW.	2	
- ,, 11.0	27	34 52	15.8	·25						
- ,, 12.0	27	40	·6	·52	15.6	92	3—4	WNW.	2	
- ,, 13.0	28	29	·8							
- ,, 14.0	29	15	16.2	·60	14.0	98	10	NW.	2	R
- ,, 15.0	30	4	15.8							
- ,, 16.02	30	33 55	16.0	·61	·6	92	8—9	NW.	2	83
- ,, 17.0	,,	,,	15.6							,,
- ,, 18.0	,,	,,	·9	·57	·6	86	10	NW.	3	,, R
- ,, 19.0	,,	,,	·8							,,
- ,, 20.0	,,	,,	·8	·53	·6	86	10	NW.	3	,, R
- ,, 21.0	,,	,,	·8							,,
- ,, 22.0	,,	,,	·8	·53	·6	91	10	WNW.	2-3	,,
- ,, 23.0	30	56	·9		*14.0*			WNW.	3-4	
- ,, 24.0	28	52	16.1	·55	·4	89	10	NNW.	2-3	
- 15. 1.0	24	39	·2							
- ,, 2.0	21	31	·3	·57	·0	98	10	N.	2-3	
- ,, 3.0	18	22	·4							
- ,, 4.0	15	13	·4	·54	15.0	92	10	NNW.	2-3	R
- ,, 5.0	12	3	·2	·53						
- ,, 6.0	9	32 53	·3	·52	·2	88	7—8	NNW.	2-3	
- ,, 7.0	6	43	·6	·52						
- ,, 8.0	3	34	·7	·53	·2	86	6—7	N.	2-3	
- ,, 9.0	0	25	17.1							
- ,, 10.0	3)	3)	·1	·73	·4	84	2—3	N.	2	
- ,, 11.0			·1							
- ,, 12.0	4	25	·2	·72	·6	85	5—6	N.	2	
- ,, 13.06			16.8							
- ,, 14.0			·9	·66	·8	85	6—7	NW.	1-2	

1) Tow-netting from 11.0 to 18.30. 2) Tow-netting from 11.0 to 20.45. 3) Tow-netting from 10 to 18.

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)	(0–6)	
VII. 15.	18.0			15·7	35·31	16·0	90	4—5	NW. 1	
- ,,	19.0	48 8	32 14	·6	·27					
- ,,	20.0	6	5	·4	·23	15·4	92	3—4	C.	
- ,,	21.0	3	31 53	·8						
- ,,	22.0	47 58	41	16·4	·64	·2	94	9	C.	85
- ,,	23.0	,,	,,	·4	·67					,,
- ,,	24.0	,,	,,	·4	·64	·8	92	9		,,
- 16.	1.25	,,	,,	·4						,,
- ,,	2.0	,,	,,	·4	·67	*15·7*	92	9	C.	,,
- ,,	3.0	55	33	·2	·51					
- ,,	4.0	52	23	·3	·58	·4	91	8—9		
- ,,	5.0	48	13	·4						
- ,,	6.0	44	1	·6	·67	·6	86	7	S. 1	
- ,,	7.0	40	30 50	·8						
- ,,	8.0	36	40	17·4	·86	·8	88	6—7	SSE. 1	
- ,,	9.0	32	28	·9	·84					
- ,,	10.0	29	20	18·4	·91	17·6	83	7—8	C.	
- ,,	11.0	,,	,,	17·8	·87					
- ,,	12.0	,,	,,	18·6	·92	·4	85	7—8	S. 0-1	
- ,,	14.0	,,	,,	·8	·99	·8	86	6—7	S. 0-1	
- ,,	15.0	,,	,,	·5						
- ,,	16.10	,,	,,	·8	36·03	18·2	87	3	C.	
- ,,	17.0	,,	,,	·45						86
- ,,	18.0	,,	,,	·3	·01	·6	89	2	C.	,,
- ,,	19.0	,,	,,	·9	·02					,,
- ,,	20.0	,,	,,	·55		*17·6*	91	2	C.	,,
- ,,	21.0	27	15	·65	·07					
- ,,	22.0	24	4	·6	·04	·3	87	1	C.	
- ,,	23.0	21	29 52	·45	35·98					
- ,,	24.0	19	43	17·95	·79	16·8	86	1	ESE. 0-1	
- 17.	1.0	15	30	18·35						
- ,,	2.0	12	17	·5	·93	·4	90	1	C.	
- ,,	3.0	9	4	·0						
- ,,	4.0	6	28 50	17·65	·77	·4	90	1	C.	
- ,,	5.0	3	36	·35	·70					
- ,,	6.0	46 59	23	·55	·72	17·6	89	3—4	C.	
- ,,	7.0	55	11	·45	·73					
- ,,	8.0	51	27 58	16·45	·74	·2	93	5—6	C.	
- ,,	9.0	¹)	¹)	18·05						
- ,,	10.0			·25	·76	·6	93	2—3	E. 1	
- ,,	11.0			·35						
- ,,	12.0	48	46	19·1	·81	18·8	89	3	NNW. 1	
- ,,	13.0			·4						
- ,,	18.0	48	44	18·75		·4	95	0—1	NW. 1	87

Date.	Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)	(0–6)	
VII. 17.	19.10	46 48	27 44	18·7						87
- ,,	20.0	,,	,,	·35		18·2	95	0—1	WNW. 1	,,
- ,,	21.0	,,	,,	·25						,,
- ,,	22.0	44	39	17·6	35·79	*18·0*	96	0—1	W. 1	
- ,,	23.0	38	31	18·25						
- ,,	24.0	32	23	·05	·71	·0	98	1	W. 1	
- 18.	1.0	26	14	·4	·78					
- ,,	2.0	18	5	·35	·75	·0	97	1—2	SW. 1	
- ,,	3.0	12	26 57	·25	·71					
- ,,	4.0	7	50	17·75	·64	17·9	98	1	SW. 1	
- ,,	5.0	1	42	·75						
- ,,	6.0	45 55	33	18·05	·77	18·2	98	3	WNW. 1	
- ,,	7.0	49	24	·4						
- ,,	8.0	41	14	·3	·71	·8	98	9	NW. 1	
- ,,	9.0	33	3	·8	·80					
- ,,	10.0	27	25 56	·9	·78	19·2	97	9	W. 1	
- ,,	11.0	26	55	19·0						88
- ,,	12.0	,,	,,	·1	·78	·8	96	8—9	WNW. 1	,,
- ,,	14.0	²)	²)	·3	·82	·4	[100]		NW. 1	F
- ,,	15.0			·2						
- ,,	16.0			·1	·80	·2	[100]		WNW. 1	F
- ,,	17.0			·25						
- ,,	18.0	12	46	18·9	·80	18·8	[100]		NNW. 1	88 A
- ,,	19.0	,,	,,	·6						,,
- ,,	20.0	,,	,,	·95	·82	19·2	98	10	NNW. 1	,,
- ,,	23.0	,,	,,	·95	·80	*18·9*	100	10	NNW. 1-2	,,
- ,,	24.0	³)	³)	·85	·81	·6	[100]	10	NNW. 1-2	
- 19.	1.0			·95						
- ,,	2.0			19·05	·84	19·0	100	10	NNW. 1	
- ,,	3.0			·25						
- ,,	4.0			·05	·77	18·0	[100]	10	NW. 2	
- ,,	5.0			·2						
- ,,	6.0			·2	·75	·6	[100]	10	NW. 2	
- ,,	7.0			·15						
- ,,	8.0			·25	·77	19·0	100	10	NW. 2	
- ,,	9.0			·25						
- ,,	10.10	28	24	·2	·80	·2	100	10	NW. 2	88 B
- ,,	11.0	,,	,,	·25						,,
- ,,	12.0	,,	,,	·6	·83	·4	98	10	NW. 2	,,
- ,,	13.0	30	14	·35						
- ,,	14.0	32	3	18·5	·71	·2	100	9—10	NW. 2	
- ,,	15.0	34	24 52	·85	·83					
- ,,	16.0	36	40	·6	·77	18·9	100	9—10	NW. 2-3	
- ,,	17.0	38	27	·35	·70					

¹) Tow-netting from 9 to 16 o'cl. ²) Trawling from 12.30 to 18.0. ³) Tow-netting from 18. July 23.0 to 19, July 10.0.

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0-10)	(0—6)	
VII. 19. 18.15	45 40	24 12	18·1	35·60	18·6	100	2—3	NW. 2-3	
- „ 19.0	41	3	·15	·64					
- „ 20.0	42	23 52	·75	·75	·8	97	9—10	NW. 2-3	
- „ 21.0	44	38	·65						
- „ 22.0	46	27	·75	·74	·8	96	10	WNW. 2	
- „ 23.0	48	15	·55						
- „ 24.0	50	5	·6	·73	19·0	93	10	NNW. 2-3	
- 20. 1.0	52	22 53	·95	·74					
- „ 2.0	54	39	19·25	·88	18·8	96	4—5	NW. 2-3	
- „ 3.0	56	28	·2	·90					
- „ 4.0	55	24	·15	·87	·8	98	8—9	WNW. 2	**89**
- „ 5.0	„	„	·15						„
- „ 6.0	„	„	·2	·90	*19·3*	98	2	WNW. 2	„
- „ 7.0	58	12	·05						
- „ 8.0	46 0	1	18·45	·74	·6	96	2	WNW. 2	
- „ 9.0	3	21 49	·6	·74					
- „ 10.0	6	38	·95	·77	20·2	96	3—4	WbN. 2	
- „ 11.0	9	27	·9						
- „ 12.0	10	22	·6	·75	19·9	97	3—5	WSW. 2	
- „ 14.0	16	4	·7	·60	20·0	96	2—3	W. 3-4	
- „ 15.0	18	20 57	·35						
- „ 16.0	20	50	·35	·62	19·6	98	7—8	W. 3	
- „ 17.0	23	43	·45						
- „ 18.0	25	36	·3	·70	·2	100	10	W. 3-4	
- „ 19.0	28	29	·4						
- „ 20.0	30	22	·55	·72	·2	[100]	10	W. 4-5	
- „ 21.0	32	15	·65	·74					
- „ 22.0	35	8	·45	·70	·1	[100]	10	W. 3	
- „ 23.0	37	2	·4	·67					
- „ 24.0	39	19 56	·45	·69	·0	[100]	10	W. 3	
- 21. 1.0	41	48	·3						
- „ 2.0	43	42	·35	·70	18.8	[100]	10	W. 4	R
- „ 3.0	46	35	·45						
- „ 4.0	48	28	17·6	·62	·8	[100]	10	W. 4	R
- „ 5.0	51	21	18·15	·64					
- „ 6.0	53	15	·0	·57	·6	[100]	10	W. 3-4	R
- „ 7.0	55	11	17·9	·61					
- „ 8.0	57	8	18·05	·58	17.4	[100]	10	NW. 3-4	R
- „ 9.0	58	6	17·9						**90**
- „ 10.0	„	„	·85	·61	16.0	98	10	NWbN. 2	„ R
- „ 11.0	„	„	·6						„
- „ 12.0	„	„	·6	·63	·4	98	10	NWbN. 1-2	„ R
- „ 13.0	„	„	18·1						„
- „ 14.40	1)	1)	·05		17·0	88	10	NWbN. 2	

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
VII. 21. 15.0			18·15						
- „ 16.0			·05	35·67	17·2	90	9—10	NWbN. 2	
- „ 17.0			·1	·67					
- „ 18.45			17·95	·68	·2	86	4—5	NWbN. 2-3	
- „ 20.0	47 5	19 10	18·05	·69	·0	89	5—6	NWbN. 2-3	
- „ 21.0	7	18 59	17·55						
- „ 22.0	9	48	·85	·68	·0	90	3—4	NW. 3	
- „ 23.0	11	40	·5						
- „ 24.0	13	29	·25	·69	16·6	88	2—3	NW. 3-4	
VII. 22. 1.0	15	17	·35	·63					
- „ 2.0	17	7	·05		·2	92	8—9	NW. 3-4	
- „ 3.0	19	17 56	16·75	·54					
- „ 4.0	21	46	·95	·59	14·8	[100]	8—9	NW. 3-4	
- „ 5.0	22	37	·85						
- „ 6.0	24	27	·6	·56	16·2	92	4—5	NW. 4-5	
- „ 7.0	25	18	·55						
- „ 8.0	27	8	·25	·48	·4	92	9—10	NW. 4-5	
- „ 9.0	29	16 58	·75	·56					
- „ 10.0	31	48	·9	·40	·3	89	4—5	NNW. 4-5	
- „ 11.0	32	38	·55	·51					**91**
- „ 12.20	„	„	·65		*16·5*	85	3—4	NNW. 4-5	„
- „ 13.0	„	„	·65						„
- „ 14.30	„	„	·5	·48	14·8	94	9	NNW. 4-5	„ R
- „ 15.0	„	„	·55						„
- „ 17.0	„	„	·5	·55	·8	94	9	NNW. 4-5	„ R
- „ 18.0	„	„	·45	·52	15·8	85	5	NNW. 3-4	„
- „ 19.0	„	„	·45						„
- „ 20.0	„	„	·25	·50	·4	86	10	NNW. 2-3	„
- „ 21.0	34	33	·45	·54					
- „ 22.0	38	21	·4	·59	·5	90	4—5	NNW. 3	
- „ 23.0	42	10	·95	·67					
- „ 24.0	45	0	17·05	·64	·6	88	9—10	NNW. 3	
VII. 23. 1.0	49	15 49	16·95						
- „ 2.0	54	34	·85	·64	14·8	90	7—8	NNW. 3	
- „ 3.0	58	23	·65						
- „ 4.0	48 2	12	·05	·58	·6	88	6—7	N. 2-3	
- „ 5.0	6	0	·35	·60					
- „ 6.0	10	14 48	·05	·57	·2	98	7—8	N. 3	
- „ 7.0	14	36	·2	·53					
- „ 8.0	18	24	·4	·58	15·4	89	3—4	NbW. 2-3	
- „ 9.0	23	10	·05						
- „ 10.0	28	13 58	·4	·60	·6	85	2—3	NbW. 2-3	
- „ 11.0	29	55	·4						**92**
- „ 12.0	„	„	·4	·57	16·0	81	2—3	NWbN. 2-3	„

1) Tow-netting from 13.0 to 19.40.

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
VII. 23. 13.0	48 29	13 55	16·45						**92**
- „ 14.15	„	„	·55		16·3	83	3	NW. 2-3	„
- „ 15.0	„	„	·55						„
- „ 16.20	„	„	·55	35·58	·2		3	WNW. 2	„
- „ 18.0	„	„	·6		·3		2—3	W. 2-3	„
- „ 19.0	„	„	·6						„
- „ 20.0	[1]	[1]	·55	·58	·2		2—3	W. 2-3	
- „ 21.0			·35						
- „ 22.0			·35	·57	·6		2—3	W. 2-3	
- „ 23.0			·5						
- „ 24.0			·55	·58	·8	88	8—9	W. 3-4	
- 24. 1.0			·55						
- „ 2.0			·45		·7	95	10	WSW. 3	
- „ 5.0			·45						
- „ 6.0			·45	·55	·6	98	10	W. 4	
- „ 7.0	41	59	·5						
- „ 8.0	44	54	·45	·58	17·0	98	10	W. 4	
- „ 9.0	47	49	·55	·52					
- „ 10.0	51	42	·4	·57	·4	94	3—4	W. 4	
- „ 11.0	54	37	15·8	·55					
- „ 12.0	57	32	·7	·52	·2	97	4	W. 4	
- „ 13.0	49 2	24	·6						
- „ 14.0	8	13	·5	·54	15·8	90	8—9	W. 4	
- „ 15.0	13	5	·9						
- „ 16.0	16	0	·65	·57	·8	90	9—10	WNW. 5	
- „ 17.0	18	12 56	·55						
- „ 18.0	23	52	·55	·55	·6	86	8—9	NWbW. 5	
- „ 19.0	25	48	·5						
- „ 20.0	27	44	·45	·54	·4	86	7—8	NW. 5	
- „ 21.0	30	40	·45						
- „ 22.0	32	36	·65	·50	·2	94	5	NW. 4	
- „ 23.0	34	33	·55						
- „ 24.0	36	30	·45	·52	·2	88	5—6	NW. 4	
- 25. 1.0	38	25	·35						
- „ 2.0	40	20	·45	·54	14·8	90	7—8	NW. 4-5	
- „ 3.0	43	14	·35						
- „ 4.0	46	9	·35	·53	15·0	88	6—7	NNW. 4-5	
- „ 5.0	46	9	·05	·54					
- „ 6.0	46	9	·1	.53	14·7	87	7—8	NNW. 4-5	
- „ 7.0	46	9	·05						
- „ 8.0	46	9	14·85	·51	·8	88	7—8	NNW. 4-5	
- „ 9.0	46	9	·85						
- „ 10.0	46	9	·85	·51	·6	88	5—6	NNW. 4-5	
- „ 11.0	46	9	·85						

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)	(0—6)	
VII. 25. 12.0	49 46	12 9	15·1	35·54	14·8	82	4—5	NNW. 4-5	
- „ 13.0	50	11 58	·15						
- „ 14.0	54	47	14·85	·54	·8	84	4—5	NNW. 4-5	
- „ 15.0	58	35	15·15						
- „ 16.0	50 3	23	·15	·50	15·1	86	5	NW. 3	**93**
- „ 17.15	„	„	·1						„
- „ 18.0	„	„	·05		14·8	84	2—3	NWbN. 2-3	„
- „ 19.0	„	„	·05		*14·6*	86		NW. 2	„
- „ 20.0	„	„	·05	·50	·6	88	3—4	NWbN. 2-3	„
- „ 21.0	3	24	14·95						
- „ 22.0	4	25	15·15	·53	·6	84	3—4	NNW. 2	
- „ 23.0	5	26	·15						
- „ 24.0	5	27	·05	·52	·6	86	3—4	NNW. 2	
- 26. 1.0	6	28	14·85						
- „ 2.0	7	29	·45	·50	·5	88	3—4	NNW. 2	
- „ 3.0	8	30	·9						
- „ 4.0	8	31	13·95	·51	13·8	88	2—3	NNW. 0-1	
- „ 5.0	9	32	14·95						
- „ 6.0	10	33	15·15	·51	15·4	80	3	C	
- „ 7.0	11	33	·25						
- „ 8.0	12	33	·15	·52	14·2	88	9	SSW. 1	
- „ 9.0	13	33	·55						
- „ 10.0	13	33	·25		·1	91	9	SSW. 2	
- „ 12.0	[2]	[2]	13·5 ?	·50	·6	98	10	SSW. 3	
- „ 13.0			15·3						
- „ 15.0			·25						
- „ 16.0			·6	·54	16·2	(100)	9	WSW. 2	
- „ 17.0			·6						
- „ 18.0			·55	·54	·0	(100)		W. 2	F
- „ 19.0			·35						
- „ 20.0			·35	·51	·2	(100)		W. 2	F
- „ 21.0			·65						
- „ 22.0			·45		·0	100		WSW. 3	F
- „ 23.0			·35						
- „ 24.0			·85	·50	15·8	100	10	WSW. 2-3	
- 27. 1.0			·35						
- „ 2.0			·15	·46	16·0	98	3—4	WSW. 2-3	
- „ 3.0			·25						
- „ 4.0			·4	·50	15·8	98	4—5	SW. 1-2	
- „ 5.0	30	40	·45						
- „ 8.0	46	14	·45	·51	16·2	96	2—3	S. 3	
- „ 9.0	51	4	14·95						
- „ 10.0	54	10 54	15·05	·26	·2	94	8	SbW. 4	
- „ 11.0	57	46	·05						

[1] Tow netting from 23. July 19.30 to 24. July 6.30. [2] Trawling and tow-netting from 26. July 10.0 to 27. July 5.0.

Date. Hour. (Ship's Time)		Position		Sea-Surface		Atmosphere					Remarks
		Lat. N.	Long. W.	Temp.	Salinity	Temp.	Humidity	Clouds	Wind Dir.	Force	
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VII. 27.	12.0	50 53	10 50	15·15	35·27	16·2	94	8	SSW.	4	
- „	13.0	50	55	·05							96
- „	13.30	„	„	·1	·22						„
- „	14.0	51	50	·0	·16	·0	96	10	S.	3	
- „	15.0	53	39	14·75							
- „	16.0	56	27	·65	·03	15·3	99	10	SSW.	3	
- „	17.0	59	14	13·65	34·84						
- „	18.0	51 2	0	·85	·88	·1	98	10	SSW.	3	
- „	19.0	5	9 47	·95							
- „	20.0	8	37	·95	·42	·2	96	10	SSW.	3	
- „	21.0	13	23	12·55							
- „	22.0	17	9	11·95	·68	14·4	96	5	SSW.	3	
- „	23.0	20	8 56	12·6							
- „	24.0	23	42	13·55	·55	15·2	96	10	SSW.	3	
- 28.	1.15	27	25	14·55							
- „	2.0	30	16	·45	·52	·3	97	10	SSW.	3	
- „	3.0	34	4	·5							
- „	4.0	39	7 50	·45	·53	14·6	[100]	10	SSW.	3-4	R
- „	5.0	43	38	13·45							
- „	6.0	47	25	·55	·44	·0	100	10	SSW.	3-4	R
- „	7.0	51	11	·65							
- „	8.0	54	2	·55	·49	·2	98	10	SSW.	4	
- „	9.0	57	6 52	·65							
- „	10.15	52 1	40	12·9	·52	13·4	100	10	SSW.	4	
- „	11.0	5	24	·45							
- „	12.0	9	10	·65	·57	·5	97	10	SEbS.	4	R
- „	13.0	17	6		·50						
- „	14.0	25	1	·95	·22	14·2	92	8	SE.	3-4	
- „	15.0	33	5 57	13·15							
- „	16.0	43	50	·05	33·97	13·4	98	9—10	SE.	3-4	
- „	17.0	51	45	·55							
- „	18.0	59	40	14·2	·72	·8	98	10	SSE.	3	R
- „	19.0	53 8	35	12·65							
- „	20.0	16	35	·45	34·05	·2	100	10	SSE.	3	R
- „	21.0	24	34	·6							
- „	22.0	33	33	13·25		·3	99	10	SE.	1-2	R
- „	23.0	42	33	12·55							
- „	24.0	49	32	·35	33·89	·4	98	10	SE.	1-2	
- 29.	1.0	59	31	·75							
- „	2.0	54 7	30	·65	·88	·0	98	10	S.	1	R
- „	3.0	15	20	11·6							
- „	4.0	22	20	·35	·86	11·6	91	10	WNW.	4-5	R
- „	5.0	29	23	·35							
- „	6.0	36	23	·0	·89	·8	89	9	WNW.	3	

Date. Hour. (Ship's Time)		Position		Sea-Surface		Atmosphere					Remarks
		Lat. N.	Long. W.	Temp.	Salinity	Temp.	Humidity	Clouds	Wind Dir.	Force	
1910		° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VII. 29.	7.15	54 47	5 21	10·95							
- „	8.0	53	20	·95	33·89	11·6	92	9	WNW.	3	
- „	9.0	55 5	17	11·95							
VIII. 4.	10.10	55 41	6 34	11·85	34·04	13·8		5	SSE.	2	
- „	11.0	45	45	12·05							
- „	12.10	52	7 8	·6	·78	·8	83	2—3	SSE.	2	
- „	13.0	55	18	13·95							
- „	14.0	59	32	·95	·87	14·0	88	2—3	SSE.	2	
- „	15.0	56 3	47	·5							
- „	16.0	6	8 0	·45	·89	·8	83	2—3	SE.	1-2	
- „	17.0	10	14	14·05							
- „	18.0	15	28	13·55	·88	13·8	87	3	ENE.	1-2	97
- „	19.0	„	„	·45	·97	12·8	96	3	C.		„
- „	21.0	23	35	·15							
- „	22.0	25	47	·05	·89	13·2	93	5	ENE.	1	
- „	23.0	27	58	·55							
- „	24.0	29	9 10	·45	35·23	12·8	91	1—2	ENE.	0-1	
- 5.	2.30	31	12	·45	·24	·6	91	2—3	C		
- „	3.0	[1])	[1])	·55							
- „	4.0			·7	·27	·6	91	2—3	C		
- „	5.0			·6							
- „	6.0			·65	·25	13·4	91	1—2	NW.	1	
- „	7.10			·6							
- „	8.0			·95	·22	14·2	88	1	WNW.	1	
- „	9.0	33	30	14·2							98
- „	10.0	„	„	·35	·23	·4	88	1	W.	1	„
- „	11.0	„	„	·15							„
- „	12.0	38	45	·55	·19	·2	92	2	W.	1	
- „	14.0	44	10 10	·6	·25	·2	96	2	NW.	1	
- „	15.0	47	24	·15							
- „	16.0	50	38	·15	·23	·0	92	4	NW.	2	
- „	17.0	53	51	13·95							
- „	18.0	56	11 4	·85	·28	13·8	94	4	WNW.	2	
- „	19.0	59	17	14·05							
- „	20.0	57 3	32	·05	·30	·8	90	3	WNW.	2	
- „	21.0	6	45	·05							
- „	22.0	9	58	13·75	·30	·4	95	2	WNW.	2	
- „	23.0	12	12 11	·35							
- „	24.0	15	24	·35	·30	·0	96	2	WNW.	2	
- 6.	1.0	18	36	·05							
- „	2.0	21	48	·25	·33	12·8	98	2	WNW.	1	
- „	3.0	23	13 1	·35							
- „	4.0	26	13	·3	·27	13·0	91	4	SSE.	1	

[1]) Tow-netting from 1 to 9 o'cl.

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Wind Dir.	Wind Force	Remarks
1910		° ′	° ′	°C	‰	°C.	%	(0–10)		(0–6)	
VIII. 6.	5.0	57 28	13 24	13·15							
- „	6.0	31	33	12·65	35·30	13·4	93	3—4	SSE.	1-2	
- „	8.0	40	38	·4	·30	·4	98	3—4	SSE.	1-2	
- „	10.0	45	40	·45	·24	·6	98	10	SE.	2	**99**
- „	11.0	45	38	·25							
- „	12.0	46	25	·55	·26	·0	93	10	SEbS.	3	
- „	13.0	46	12	·85							
- „	14.0	47	12 57	·1	·22	·8	98	10	SEbS.	3	
- „	15.0	48	43	13·15							**100**
- „	16.0	„	„	·2	·27	12·8	[100]	10	SSE.	3	„ R
- „	17.0	„	„	·15							„
- „	18.0	„	„	·05		*13·9*	100	10	SSE.	3	„
- „	19.0	47	36	.2							
- „	20.0	46	24	12.85	·33	14·0	100	10	SSE.	3	
- „	21.0	44	12	13·15							
- „	22.0	42	11 58	·15	·30	·2	98	9	SSE.	2	
- „	23.0	41	48	·3							
- „	24.0	41	48	·45	·30	·0	100	9	SSE.	2	**101**
- 7.	1.0	„	„	·4							„
- „	2.0	„	„	·4	·32	·0	98	10	SSE.	2-3	„
- „	3.0	„	„	·25							„
- „	4.0	„	„	·15	·30	·0	98	9—10	SEbS.	2-3	„
- „	5.0	1)	1)	·1							
- „	6.0			·15	·33	13·8	100	10	SSE.	2	
- „	7.0			12·45							
- „	8.0			·6	·30	·8	100	10	SEbS.	2	
- „	9.0			13·0							
- „	12.0			14·2	·34	·8	100	10	SEbS.	2	
- „	14.0			13·15	·30	14·0	100	10	SEbS.	2	
- „	15.0			·2							
- „	16.0			·25	·30	·0	100	10	SE.	1-2	
- „	17.0			·45							
- „	18.0	27	12 5	·25		13·8	[100]		SE.	1-2	F
- „	19.0	33	11 54	·2							
- „	20.0	39	44	·45	·29	14·0	98	9	SE.	2	
- „	21.0	46	33	·55							
- „	22.0	52	23	·65	·22	13·7	97	8—9	EbS.	2	
- „	23.0	58	12	·95							
- „	24.0	58 4	2	14·15	·24	·4	98	8	EbS.	2	
- 8.	1.0	10	10 51	13·45							
- „	2.0	16	40	·65	·33	14·0	94	10	EbS.	1	R
- „	3.0	22	30	·25							
- „	4.0	29	19	·25	·34	12·8	[100]	10	C.		R
- „	5.0	36	8	·45							

Date. (Ship's Time)	Hour.	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Wind Dir.	Wind Force	Remarks
1910		° ′	° ′	°C.	‰	°C.	%	(0–10)		(0–6)	
VIII. 8.	6.0	58 42	9 58	13·65	35·29	12·7	[100]	10	E.	0-1	
- „	7.10	49	46	·15							
- „	8.0	54	38	·25	·36	·2	[100]	10	E.	0-1	
- „	9.0	59 1	27	·3							
- „	10.0	7	17	·15	·28	·2	100	10	E.	0-1	
- „	11.0	13	6	·25							
- „	12.0	19	8 56	·25	·31	·4	[100]	10	E.	1	
- „	13.0	25	46	12·65							
- „	14.15	33	33	·55	·33	·4	[100]	10	ESE.	1-2	R
- „	15.0	37	25	·45							
- „	16.0	43	15	·35	·30	13·0	98	9—10	ESE.	2	
- „	18.0	55	7 52	·25	·35	·3	99	9—10	ESE.	2	
- „	19.0	60 1	41	·35							
- „	20.0	7	30	·05	·28	12·7	99	5	E.	2-3	
- „	21.0	13	19	11·45							
- „	22.0	19	8	·5	·18	·4	100	10	E.	2	R
- „	23.0	25	6 57	·45							
- „	24.0	31	46	10·15	·23	11·6	[100]	10	E.	3	R
- 9.	1.0	37	34	11·05							
- „	2.0	43	23	10·85	·25	12·4	100	9—10	E.	3	
- „	3.0	49	11	11·65							
- „	4.0	55	5 59	·95	·20	·8	100	10	ESE.	3	
- „	5.0	61 0	58	12·35							
- „	6.0	4	6 7	11·4	·18	·6	98	10	SSE.	2	
- „	7.0	8	16	10·6							
- „	8.0	4	5 59	11·75	·24	·4	98	10	SE.	2	
- „	9.0	1	46	12·6							
- „	10.0	60 58	33	11·75	·25	·8	94	9—10	SE.	2-3	
- „	11.0	55	20	·75							
- „	12.0	52	7	·65		·7	96	8	SE.	3	
- „	13.0	50	0	12·35							
- „	14.30	46	4 46	·9	·11	13·2	100	9	ESE.	1	
- „	15.0	2)	2)	·85							
- „	16.0			·85	·22	·0	100	10	ESE.	1	
- „	17.0			13·0							
- „	18.0			12·85	·16	12·2	100	10	ESE.	1	
- „	19.0			·25							
- „	20.0			·6	·14	11·4	100	10	E.	1	
- „	22.0			·7	·16	10·8	100	10	NNE.	1	
- „	23.0			13·25							
- „	24.0			·05	·18	·4	100	10	NE.	1	
- 10.	1.0			·15							
- „	2.0			12·6	·17	·8	98	10	NE.	1	
- „	3.0	57	38	·95							

1) Trawling and tow-netting from 4 to 18 o'cl. 2) Tow-netting and trawling from 9. Aug. 14.30 to 10. Aug. 3.20.

Date. Hour. (Ship's Time)	Position Lat. N.	Position Long. W.	Sea-Surface Temp.	Sea-Surface Salinity	Atmosphere Temp.	Atmosphere Humidity	Atmosphere Clouds	Atmosphere Wind Dir. Force	Remarks
1910	° ′	° ′	°C.	‰	°C.	%	(0–10)	(0—6)	
VIII. 10. 4.0	60 54	4 25	12·75	35·21	11·0	95	10	ENE. 1	
- „ 5.0	50	10	·95						
- „ 6.0	46	3 55	13·35	·12	·2	98	10	E. 1	
- „ 7.0	42	39	12·45						
- „ 8.0	38	24	13·0	·21	12·0	96	10	ESE. 1	
- „ 9.0	34	6	·05						
- „ 10.0	30	2 49	12·6	·13	·6	98	9—10	NNE. 1	
- „ 11.30	26	34	13·15						**103**
- „ 12.40	„	„	·15	34·98	*13·0*	99	10	NNE. 1	„
- „ 13.0	27	40	·45						
- „ 14.0	31	3 1	·35	35·14	12·6	100	9—10	NNW. 1-2	
- „ 15.0	35	20	·15						**104**
- „ 16.0	„	„	·3	·21	*12·8*	100	10	NNE. 1	„
- „ 17.0	39	33	·2	·21					
- „ 18.0	43	45	12·85	·20	·4	100	10	NNE. 1	
- „ 19.0	45	50	·75						**105**
- „ 20.0	„	„	·75	·17	*12·0*	100	10	NE. 1	„
- „ 21.0	47	57	·85	·16					
- „ 22.0	51	4 14	·6	·16	·0	98	10	E. 1	R
- „ 23.0	54	28	13·05	·00					**106**
- „ 24.0	„	„	·05		·0	96	10	E. 1	„
- 11. 1.0	„	„	·0						„
- „ 2.0	„	„	·05		11·2	[100]	10	ENE. 1	„
- „ 3.0	56	35	12·95	·19					
- „ 4.0	61 0	48	·45	·18	·2	98	9	ENE. 2	
- „ 5.0	4	5 5	·0	·28					**107**
- „ 6.0	„	„	·25		·0	98	10	E. 1	„
- „ 7.0	„	„	11·85						„
- „ 8.0	6	19	12·3	·18	*11·3*	95	10	ENE. 1	
- „ 9.0	10	35	11·95	·20					
- „ 10.0	13	47	·9	·24	·4	95	9—10	E. 1	**108**
- „ 11.0	„	„	·85	·23	*11·9*	97		EbS 1	„
- „ 12.0	17	6 2	·6	·20	·8	100	9	E. 1	
- „ 13.0	20	15	·65	·19					
- „ 14.0	22	24	10·85	·17	·0	100	10	ESE. 1	**109** R
- „ 15.0	26	30	·05	·13					
- „ 21.0	36	40	9·45	·23					
- „ 22.0	37	18	·95	·15	10·8	[100]	8—9	ESE. 1-2	
- „ 23.0	38	3	·55	·16					
- „ 24.0	39	5 57	11·05	·15	11·8	[100]	10	ESE. 2	**110**
- 12. 1.0	38	51	·1	·12					
- „ 2.0	35	35	·6	·18	12.4	98	10	ESE. 2	
- „ 3.0	32	18	·6	·23					
- „ 4.0	32	16	·75	·19	·0	98	10	ESE. 2	**111**
- „ 5.0	„	„	·55	·20	11·7	95		SE 2	„
- „ 6.0	29	3	·85	·22	·8	93	9	ESE. 2	
VIII. 12. 7.0	61 26	4 44	11·75	35·25					
- „ 8.0	24	34	·3	·17	11·8	98	8—9	ESE. 2	**112**
- „ 9.0	„	„	·45						„
- „ 10.0	24	32	·85	·21	·8	100	8	ESE. 2	
- „ 11.0	21	15	12·05	·22					
- „ 12.15	16	3 50	11·85	·21	12·2	96	10	ESE. 2	**113**
- „ 13.0	„	„	·65	·20					„
- „ 14.0	„	„	12·15		11·9	[100]	9—10	ESE. 2	„
- „ 15,0	„	„	·15						„
- „ 16.0	„	„	·15		·8	93	10	ESE. 2	„ R
- „ 17.0	„	„	·15		12·2	82			„
- „ 18.0	„	„	·25		·1	81	10	ESE. 2	„
- „ 19.0	„	„	·25						
- „ 20.0	„	„	·25		·2	78	9—10	EbN. 2-3	
- „ 21.0	15	45	·25	·22					
- „ 22.0	12	33	11·95		·0	98	10	E. 3	
- „ 23.0	9	19	12·25	·21					
- „ 24.0	8	14	·35	·17	·2	98	10	E. 3	**114**
- 13. 1.0	„	„	·35						„
- „ 2.0	„	„	·35		·2	100	10	ENE. 2-3	„
- „ 2.45	„	„	·3	·16					„
- „ 4.0	4	2 57	·45	·20	·3	100	9—10	ENE. 3	
- „ 5.0	1	46	·55	·22					
- „ 6.0	0	41	·45	·20	·6	98	10	ENE. 3	**115**
- „ 7.0	„	„	·45	·20					„
- „ 8.0	„	„	·45	·20	·2	98	10	ENE. 2	„
- „ 9.20	„	„	·6	·19	·3	98		NE 2	„
- „ 10.0	„	„	·65	·17	·6	100	7—8	ENE. 2	„
- „ 11.0	„	„	·7	·21					„
- „ 12.10	„	„	·75	·24	·0	[100]			„
- „ 14.0	„	„	·75	·22	13·0	98	8	ENE. 2	„
- „ 15.0	„	„	·55	·19					„
- „ 16.10	„	„	·65	·22	12·7	99	9	ENE. 2	„
- „ 17.0	„	„	·55	·17					„
- „ 18.0	„	„	·55	·17	·8	98	8	NE. 2	„
- „ 19.0	„	„	·6	·25					„
- „ 20.0	„	„	·55	·21	·2	98	8	NE. 2	„
- „ 21.0	„	„	·55						„
- „ 22.0	„	„	·65	·22	·4	98	9—10	ENE. 2	„
- „ 23.0	„	„	·65	·22					„
- „ 24.0	„	„	·55	·20	·6	98	9—10	ENE. 2	„
- 14. 1.0	„	„	·55	·20					„
- „ 2.0	„	„	·45	·09	·6	96	8—9	ENE. 1	„
- „ 3.0	„	„	·55	·13					„
- „ 4.0	„	„	·65	·15	·2	98	8	ENE. 1	„
- „ 5.0	„	„	·7	·14					„

Date. Hour. (Ship's Time)	Position		Sea-Surface		Atmosphere					Remarks
	Lat. N.	Long. W.	Temp.	Salinity	Temp.	Humidity	Clouds	Wind Dir.	Force	
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VIII. 14. 6.0	61 0	2 41			*12·4*	88		E.	1-2	115
- „ 7.0	„	„	12·75	35·17						„
- „ 8.0	60 57	26	·95	·16	·8	85	7—8	E.	2-3	
- „ 9.0	54	10	13·05	·17						
- „ 10.0	52	1	12·6	·12	13·0	83	2—3	E.	1	116
- „ 11.0	53	1 51	13·35	·17						
- „ 12.0	56	33	·15	·14	·8	75	4	E.	1	
- „ 13.0	55	18	·0	·00						
- „ 14.0	54	0	12·85	·12	·4	100	3—4	ESE.	2	
- „ 15.0	54	0 44	·55	·15						
- „ 16.0	54	27	13·45	·11	·4	98	4	ESE.	2-3	
- „ 17.0	54	13	14·1	34·45						
		Long. E.								
- „ 18.0	54	0 3	·65	33·75	·2	98	3—4	E.	2 3	
- „ 19.0	55	18	·45	·61						

Date. Hour. (Ship's Time)	Position		Sea-Surface		Atmosphere					Remarks
	Lat. N.	Long. E.	Temp.	Salinity	Temp.	Humidity	Clouds	Wind Dir.	Force	
1910	° ′	° ′	°C.	‰	°C.	%	(0—10)		(0—6)	
VIII. 14. 20.0	60 55	0 33	14·6	33·83	13·0	98	3—4	E.	3	
- „ 21.0	55	50	·45	·72						
- „ 22.0	55	1 3	·65	·32	·0	96	4—5	E.	3	
- „ 23.0	56	19	·7	·14						
- „ 24.0	56	33	·35	·31	12·8	98	3—4	ENE.	3	
- 15. 1.0	56	50	·25	·57						
- „ 2.0	56	2 4	·05	·57	·8	100	9	E.	3	
- „ 3.0	57	19	·25	·51						
- „ 4.0	57	34	13·85	·65	13·2	98	4	E.	3	
- „ 5.0	57	50	14·25							
- „ 6.0	57	3 6	13·35	32·93	14·0	94	3	ENE.	1	
- „ 7.0	58	24	14·45	·78						
- „ 8.0	58	39	15·45	31·33	·8	94	1—2	ENE.	1	
- „ 9.0	58	59	16·1	30·61						
- „ 10.0	58	4 15	·2	29·0	·5	98	1—2	ENE.	1	

Table II. Serial Observations at the Stations.

Stat. **1**. 9. April 1910.
49° 27′ N. 8° 36′ W. 146 metres.

LMT	m	f	t °C	S ‰	σ_t
15h 0m	0	0	10·1	35·37	27·24
14 48	23	13	9·62 ·63	·36	·32
12	46	25	9·59 ·61	·36	·32
29	91	50	9·58 ·59	·35	·31
39	137	75	9·56 ·58	·36	·32

Stat. **2**. 10. April 1910.
49° 30′ N. 9° 42′ W. 149 metres.

LMT	m	f	t °C	S ‰	σ_t
0h 51m	0	0	9·6	35·25	27·23
40	23	13	9·21 ·23	·24	·29
32	46	25	9·16 ·17	·25	·305
25	91	50	9·13 ·14	·25	·31
15	137	75	9·13 ·14	·23	·30

Stat. **3**. 10. April 1910.
49° 32′ N. 10° 49′ W. 184 metres.

LMT	m	f	t °C	S ‰	σ_t
7h 2m	0	0	10·4	35·49	27·28
6 58	23	13	10·21 ·21	·48	·31
50	46	25	10·26 ·18	·46	·29
43	91	50	10·15 ·11	·47	·31
34	137	75	10·21 ·22	·47	·30
23	174	95	10·27 [·42]	·47	·29

Stat. **4 (A, B)**. 10. April 1910.
A: 49° 38′ N. 11° 35′ W. 923 metres.

LMT	m	f	t °C	S ‰	σ_t
13h 30m	0	0	10·7	35·50	27·235
0	823	450	9·19 ·21	·53	·52

B: 49° 39′ N. 11° 40′ W.

LMT	m	f	t °C	S ‰	σ_t
23h 12m	0	0	10·6	35.52	27·27
12	23	13	10·47 ·49	·46	·245
2	46	25	10·43 ·44	·48	·27
22 55	91	50	10·44 ·45	·50	·28
42	183	100	10·26 ·27	·47	·29
30	274	150	10·25 ·25	·47	·29
15	457	250	10·10 ·10	·45	·30
21 57	640	350	9·51 ·52	·48	·425

Stat. **5**. 16. April 1910.
51° 24′ N. 9° 27′ W. 68 metres.

LMT	m	f	t °C	S ‰	σ_t
14h 40m	0	0	8·4	34·66	26·96
32	9	5	8·34	·67	·98

LMT		m	f	t °C	S ‰	σ_t
14h	24m	23	13	8·29 ·31	34·66	26·98
	18	46	25	8·26 ·28	·81	27·10
	9	64	35	8·30 ·32	·84	·12

Stat. 6. 16. April 1910.
50° 33′ N. 10° 42′ W. 168 metres.

LMT		m	f	t °C	S ‰	σ_t
24h	0m	0	0	9·9	35·43	27·32
	20	23	13	9·93 ·95	·44	·32
	13	46	25	9·91 ·92	·45	·34
	4	91	50	9·91 ·92	·44	·33
23	56	160	88	9·88 ·89	·45	·34

Stat. 7. 17. April 1910.
49° 54′ N. 12° 10′ W. 1813 metres.

LMT		m	f	t °C	S ‰	σ_t
15h	42m	0	0	10·6	35·46	27·23
14	26	46	25	10·41 ·43	·45	·245
	19	91	50	10·40 ·41	·44	·24
	10	183	100	10·27 ·29	·48	·29
15	53	457	250	10·01 ·02	·46	·33
	12	914	500	8·34 ·35	·47	·615
	34	1280	700	5·73 ·74	·19	·76
14	46	1601	875	3·89 ·88		

Stat. 8. 18. April 1910.
48° 53′ N. 11° 31′ W.

LMT		m	f	t °C	S ‰	σ_t
10h	40m	0	0	10·95	35·49	27·18
	43	91	50	10·71 ·72	·48	·21
	33	457	250	10·48 ·49	·46	·245
	19	914	500	9·07 ·08	·61	·61

Stat. 9. 18. April 1910.
47° 49′ N. 10° 52′ W.

LMT		m	f	t °C	S ‰	σ_t
19h	50m	0	0	11·0	35·54	27·215
	15	91	50	10·72 ·73	·51	·235
	33	457	250	10·45 ·46	·46	·25
	15	914	500	9·28 ·28	·52	·50

Stat. 10 & 10 A. 19—20. April 1910.
45° 26′ N. 9° 20′ W. 4700 metres.

10 (19. April):

LMT		m	f	t °C	S ‰	σ_t
17h	0m	0	0	12·3	35·56	26·98
16	40	46	25	11·44 ·44	·59	27·17
	18	91	50	11·24 ·24	·59	·21
14	41	183	100	11·13 ·07	·54	·195
16	30	„	„	11·13 ·13	·54	·19
14	30	274	150	10·96 [11·23]	·52	·21
16	5	457	250	10·72 ·72	·54	·26
14	10	640	350	10·29 ·29	·54	·34
15	50	„	„	10·52	·54	·30
14	11	914	500	10·33 ·26	·86	·59
15	26	„	„	10·24 ·24	·83	·57
	28	1372	750	[7·63] ·51	·54	·79

10 A (20. April):

LMT		m	f	t °C	S ‰	σ_t
15h	2m	1829	1000	[4·65] ·30	35·075	27·83
14	53	3000	1640	2·44		
15	0	4500	2461	2·56 ·55		

Stat. 11. 21. April 1910.
44° 25′ N. 9° 18′ W.

LMT		m	f	t °C	S ‰	σ_t
13h	46m	0	0	11·95	35·61	27·09
14	15	91	50	11·41 ·43	·61	·19
	8	183	100	11·12 ·13	·54	·19
13	41	457	250	10·61 ·62	·53	·28
	56	640	350	10·57 ·58	·57	·315
	21	914	500	10·89 ·90		

Stat. 12. 21. April 1910.
43° 11′ N. 9° 26′ W. 166 metres.

LMT		m	f	t °C	S ‰	σ_t
22h	51m	0	0	13·6	35·47	26·65
23	6	„	„	·15	·46	·735
	31	9	5	12·17 ·19	·47	·94
	20	23	13	12·19 ·19	·48	·94
23h	11m	46	25	12·09 ·09	35·52	26·99
	2	91	50	11·70 ·72	·61	27·135
22	54	137	75	11·59 ·60	·61	·16
	42	160	88	11·47 ·47	[·47?]	[·08]

Stat. 13. 22. April 1910.
41° 32′ N. 9° 5′ W. 78 metres.

LMT		m	f	t °C	S ‰	σ_t
11h	54m	0	0	15·2	33·84	25·06
	55	9	5	14·4*	34·57	·79
	20	46	25	12·35 ·37	35·57	26·97
	35	„	„	12·4*	·57	·98
	49	64	35	12·0*	·61	27·08

Stat. 16. 23. April 1910.
40° 15′ N. 9° 23′ W. 154 metres.

LMT		m	f	t °C	S ‰	σ_t
7h	7m	0	0	13·9	35·56	26·66
	25	23	13	13·82 ·82	·53	·65
	17	46	25	13·10 ·11	·58	·84
	7	91	50	12·83 ·84		
6	57	137	75	12·46 ·47	·72	27·08

Stat. 17. 23. April 1910.
38° 20′ N. 9° 43′ W. 1860 metres.

LMT		m	f	t °C	S ‰	σ_t
23h	9m	0	0	14·8	35·81	26·655
21	11	23	13	14·80 ·80	·81	·655
	24	46	25	13·97 ·99	·82	·84
	34	91	50	13·81 ·82	·89	·93
	44	183	100	13·23 ·24	·86	27·03
23	54	274	150	12·27 ·28	·72	·115
	40	457	250	11·18 ·20	·63	·25
	19	914	500	10·69 ·70	36·30	·86
22	49	1372	750	10·51 ·51	·31	·90
	9	1646	900	6·58 ·60	35·54	·92

Stat. 18 (A, B, C, D). 29—30. April 1910.
35° 56′ N. 5° 43′ W. 400 metres.

A (29. April):

LMT		m	f	t °C	S ‰	σ_t
12h	7m	0	0	17·0	36·12	26·40
11	34	23	13	15·16 ·17	·19	·87
	42	46	25	13·29 ·28	37·80	28·52

LMT	m	f	t °C	S ‰	σ_t
11h 57m	91	50	12·91 ·94	38·30	28·99
24	183	100	12·91 ·91	·39	29·06
11	274	150	12·88 ·85	·39	·07
6	366	200	12·88 ·88		

B (29. April):

LMT	m	f	t °C	S ‰	σ_t
14h 7m	0	0	16·6	36·14	26·49
13 45	20	11	14·89 ·90		
52	40	22	13·34 ·36		
14 1	85	46	12·92 ·91	38·33	29·015

C (29—30. April):

LMT	m	f	t °C	S ‰	σ_t
0h 42m	0	0	16·6	36·02	26·41
23 4	23	13	15·60 ·59		
12	46	25	15·09 ·08	·20	·90
22	95	52	14·38 ·38	·28	27·11
32	194	107	13·10 ·11	37·97	28·68
44	274	150	12·89 ·89	38·39	29·06

D (30. April):

LMT	m	f	t °C	S ‰	σ_t
9h 57m	0	0	17·4	36·17	26·33
32	20	11	16·18		
42	40	22	15·39 ·40		
52	85	46	14·09 ·10		
17	180	98	12·94 ·94	38·36	29·03

Stat. **19 A.** 2. May 1910.
36° 5′ N. 4° 42′ W.

LMT	m	f	t °C	S ‰	σ_t
10h 51m	0	0	16·4	36·36	26·73
11 19	23	13	15·75 ·75	·36	·86
10 54	46	25	14·76 ·76	·44	27·15
44	91	50	14·46 ·48	·62	·35
11 6	137	75	13·24 ·25	37·95	28·65
10 33	183	100	12·96 ·96	38·32	·99
19	274	150	12·95 ·96		
9	366	200	12·93 ·94	·42	29·075
9 51	457	250	12·91 ·92	·42	·08
11 59	549	300	12·90 ·88	·41	·075

LMT	m	f	t °C	S ‰	σ_t
12h 37m	686	375	12·86 ·86	38·42	29·09
18	869	475	12·84 ·84	·39	·065

Stat. **19 B.** 2. May 1910.
36° 5′ N. 4° 40′ W.

LMT	m	f	t °C	S ‰	σ_t
17h 26m	0	0	16·9	36·39	26·62
18	46	25	14·69 ·71	·46	27·18
10	91	50	14·22 ·23	·91	·63
1	137	75	13·24 ·22	37·98	28·67

Stat. **19 C.** 2. May 1910.
36° 8′ N. 4° 25′ W.

LMT	m	f	t °C	S ‰	σ_t
11h 28m	0	0	16·7	36·40	26·68
0	48	26	14·73 ·73	·48	27·19
10 51	97	53	13·83 ·83	37·30	28·01
38	150	82	13·06 ·06	38·17	·85
24	240	131	12·96 ·94	·35	29·015

Stat. **20.** 5. May 1910.
35° 25′ N. 6° 25′ W. 141 metres.

LMT	m	f	t °C	S ‰	σ_t
4h 9m	0	0	16·8	36·27	26·55
4	9	5	16·75	·26	·55
3 54	23	13	16·41	·29	·66
44	46	25	14·96 ·96	·20	·92
34	91	50	14·12 ·11	·05	·99
17	137	75	12·98 ·98	35·83	27·06

Stat. **21.** 5. May 1910.
35° 31′ N. 6° 35′ W. 535 metres.

LMT	m	f	t °C	S ‰	σ_t
10h 6m	0	0	17·5	36·36	26·45
1	457	250	11·52 ·52	35·63	27·19

Stat. **22.** 5. May 1910.
35° 42′ N. 6° 51′ W. 835 metres.

LMT	m	f	t °C	S ‰	σ_t
16h 28m	0	0	18·6	36·37	26·19
53	46	25	16·31	·32	·705
45	91	50	15·32 ·32	·28	·90
14	183	100	13·82 ·82	35·92	·95
15 47	274	150	12·64 ·64	·80	27·10
33	366	200	11·88 ·87	·70	·175
21	457	250	11·24 ·24	·62	·235

LMT	m	f	t °C	S ‰	σ_t
15h 5m	549	300	10·83 ·82	35·61	27·30
16 23	640	350	10·69 ·68	·66	·37
1	732	400	10·64 ·63	·73	·43

Stat. **23.** 5. May 1910.
35° 32′ N. 7° 7′ W. 1215 metres.

LMT	m	f	t °C	S ‰	σ_t
20h 7m	0	0	17·9	36·36	26·36
7	23	13	17·27	·35	·505
0	46	25	15·86 ·88	·28	·78
19 54	91	50	15·18 ·18	·25	·91
36	183	100	14·15 ·15	·04	·97
20 17	274	150	12·76 ·75	35·81	27·09
30	366	200	11·87 ·86	·63	·12
21 17	549	300	10·84 ·84	·56	·26
57	732	400	10·52 ·52	·71	·43
37	914	500	10·06 ·06	·81	·59
52	1097	600	10·17 ·17	·99	·71

Stat. **24.** 6. May 1910.
35° 34′ N. 7° 35′ W. 1615 metres.

LMT	m	f	t °C	S ‰	σ_t
19h 52m	0	0	17·9	36·39	26·38
37	1441	788	7·99 8·01		

Stat. **25 A.** 7. May 1910.
35° 36′ N. 8° 25′ W. 2300 metres.

LMT	m	f	t °C	S ‰	σ_t
11h 33m	0	0	17·8	36·34	26·37
13	1966	1075	4·38 ·37	35·10	27·85

Stat. **25 B.** 8. May 1910.
35° 46′ N. 8° 16′ W.

LMT	m	f	t °C	S ‰	σ_t
9h 12m	0	0	17·8	36·41	26·42
5 41	23	13	17·78	·37	·40
9 53	46	25	15·92 ·94	·25	·74
47	91	50	15·14 ·15	·21	·89
40	183	100	13·60 ·59		
31	274	150	12·73 ·72	35·79	27·07
5 20	366	200	11·88 ·87	·62	·11
8 32	,,	,,	11·96 ·96	·64	·11
9 20	457	250	11·43 ·42	·56	·15
8 48	549	300	11·24 ·22	·59	·21

LMT	m	f	t °C	S ‰	σ_t
9h 5m	686	375	11·40 ·39	35·88	27·40
8 1	800	438	11·32		
6 37	914	500	10·77 ·76	·99	·60
7 7	1097	600	11·05 ·05	36·22	·73
30	1280	700	10·10 ·10	·13	·84
8 4	1463	800	7·81 ·81	35·71	·88
6 9	1829	1000	5·27 ·27	·26	·87

Stat. **26**. 8. May 1910.
36° 53′ N. 6° 48′ W. 50 metres.

LMT	m	f	t °C	S ‰	σ_t
21h 10m	0	0	16·8	35·91	26·28
30	9	5	16·76	·84	·235
14	23	13	14·91 ·91	·93	·73
22	37	20	13·53 ·54	·89	·99
6	46	25	13·39 ·40	·88	27·01

Stat. **27**. 9. May 1910.
36° 31′ N. 7° 1′ W.

LMT	m	f	t °C	S ‰	σ_t
1h 30m	0	0	17·42	36·37	26·48
52	23	13	17·27	·36	·52
26	46	25	16·36	·31	·69
2 44	91	50	15·37 ·36	·25	·87
22	183	100	13·98 ·99	35·97	·96
35	274	150	13·02 ·01	·81	27·04
1 43	366	200	11·94 ·92	·63	·11
12	457	250	12·36 ·35	36·03	·33

Stat. **28**. 9. May 1910.
36° 0′ N. 7° 19′ W.

LMT	m	f	t °C	S ‰	σ_t
7h 29m	0	0	17·5	36·35	26·445
9 11	23	13	17·19	·34	·515
4	46	25	16·80	·32	·59
6 44	91	50	15·41 ·42	·21	·83
7 13	183	100	14·47 ·47	·07	·93
23	274	150	13·17 ·17	35·87	27·05
6 57	366	200	12·17 ·17	·69	·11
33	457	250	11·36 ·35	·55	·155
7 40	549	300	11·02 ·01	·52	·19
57	640	350	10·66 ·66	·57	·30
8 53	732	400	10·61 ·60	·65	·37
36	823	450	10·94 ·95	36·06	·63

Stat. **29**. 9—10. May 1910.
35° 10′ N. 7° 55′ W.

LMT	m	f	t °C	S ‰	σ_t
0h 8m	0	0	17·8	36·36	26·38
0	23	13	17·96	·35	·33
10	46	25	16·09		
19	91	50	15·25 ·26	·21	·865
31	183	100	13·57 ·56	35·90	·99
43	274	150	12·64 ·63	·72	27·045
22 23	366	200	11·82 ·81	·62	·125
35	549	300	11·22 ·22	·68	·28
52	732	400	10·73 ·73		
23 13	914	500	10·75 73	36·00	·62
42	1097	600	10·92 91	·17	·72

Stat. **30**. 10. May 1910.
34° 38′ N. 8° 22′ W.

LMT	m	f	t °C	S ‰	σ_t
8h 17m	0	0	17·4	36·39	26·505
32	23	13	·38	·33	·46
38	46	25	16·03	·28	·74
45	91	50	15·86 ·86	·31	·79
24	183	100	13·92 ·92	35·92	·93
13	274	150	13·01 ·00	·81	27·04
5 53	366	200	12·25 ·25	·74	·135
6 8	549	300	11·14 ·13	·64	·265
7 57	640	350	11·08 ·07	·74	·36
6 24	732	400	11·44 ·43	·96	·46
8 57	823	450	10·69 ·67	·92	·57
6 47	914	500	10·60 ·60	·97	·62
7 34	1006	550	10·62 ·61	36·09	·72
7 9	1097	600	10·64 ·63	·13	·745
9 21	1280?	700?	10·69 ·67	35·96	·60

Stat. **31**. 10. May 1910.
33° 47′ N. 8° 27′ W. 184 metres.

LMT	m	f	t °C	S ‰	σ_t
16h 0m	0	0	17·7	36·33	26·38
31	9	5	17·91	·36	·35
22	23	13	17·48	·35	·445
26	37	20	16·23	·31	·715
18	46	25	16·10	·25	·695
15 55	91	50	14·85 ·85	·14	·90
16h 12m	137	75	13·96 ·95	36·02	27·00
5	174	95	13·42 ·42	35·89	·01

Stat. **32**. 10. May 1910.
33° 27′ N. 8° 32′ W. 105 metres.

LMT	m	f	t °C	S ‰	σ_t
20h 15m	0	0	17·9	36·21	26·24
8	23	13	17·49		
15	37	20	15·00 14·99	·10	·84
2	46	25	14·92 ·92		
19 55	73	40	13·70 ·70		
20 21	91	50	13·58 ·57		
19 46	101	55	13·61 ·61		

Stat. **33**. 11. May 1910.
31° 17′ N. 10° 6′ W. 100 metres.

LMT	m	f	t °C	S ‰	σ_t
18h 55m	0	0	16·3	36·06	26·51
52	46	25	16·20	·22	·66
47	91	50	14·96 ·96	·16	·89

Stat. **34**. 13. May 1910.
28° 52′ N. 14° 16′ W. 2170 metres.

LMT	m	f	t °C	S ‰	σ_t
16h 49m	0	0	18·1	36·69	26·56
34	23	13	18·92	·56	·25
17 22	46	25	17·98	·59	·51
29	91	50	17·18	·55	·68
38	183	100	16·38	·38	·74
20 17	274	150	13·97 ·97	35·96	·95
19 16	366	200	12·87 ·88	·79	27·05
18 17	457	250	11·76 ·76	·64	·15
19 34	640	350	10·46 ·46	·56	·33
17 4	914	500	8·50 ·51	·42	·545

Stat. **35**. 18. May 1910.
27° 27′ N. 14° 52′ W. 2603 metres.

LMT	m	f	t °C	S ‰	σ_t
12h 57m	0	0	18·6	36·37	26·19
6	9	5	18·56	·33	·17
13	23	13	18·47	·33	·19
20	46	25	17·92	·42	·395
30	91	50	16·86	·42	·655
40	183	100	15·20 ·20	·11	·80

Stat. **36**. 19. May 1910.
26° 12′ N. 14° 26′ W. 10 metres.

LMT	m	f	t °C	S ‰	σ_t
18h 50m	0	0	16·4	36·20	26·59
45	2	1	16·27	·14	·58
32	5	3	16·20	·17	·62
23	9	5	15·78	·17	·71

Stat. **37**. 20. May 1910.
26° 6′ N. 14° 33′ W. 39 metres.

LMT	m	f	t °C	S ‰	σ_t
8h 33m	0	0	17·65		
28	9	5	16·56		
21	23	13	15·68 ·67	36·17	26·74
12	39	21	15·62 ·64	·14	·73

Stat. **38**. 20. May 1910.
26° 3′ N. 14° 36′ W. 77 metres.

LMT	m	f	t °C	S ‰	σ_t
11h 36m	0	0	19·2	36·15	25·87
27	9	5	18·07	·15	26·15
21	46	25	15·84 ·85	·23	·745
11	73	40	15·76 ·74	·22	·76

Stat. **39 A**. 20. May 1910.
26° 3′ N. 15° 0′ W. 214 metres.

LMT	m	f	t °C	S ‰	σ_t
18h 20m	0	0	19·2	36·48	26·12
17	9	5	18·84	·45	·19
10	23	13	18·47	·46	·29
2	46	25	18·02	·45	·395
17 55	91	50	17·78	·44	·45
46	183	100	16·73	·42	·685
35	206	113	16·27	·33	·725

Stat. **40**. 22—23. May 1910.
28° 15′ N. 13° 29′ W. 1197 metres.

LMT	m	f	t °C	S ‰	σ_t
21h 56m	0	0	18·4	36·44	26·29
22 1	9	5	18·49	·42	·25
21 51	23	13	18·49	·42	·25
41	46	25	17·69	·43	·46
31	91	50	16·86	·39	·64
22 10	183	100	15·67 ·65	·39	·92
0 36	265	145	14·36 ·25		
24	357	195	13·11 ·10		
11	457	250	11·72 ·69	35·59	27·12
23 54	640	350	9·50 ·47	·34	·32
38	823	450	7·97 ·96	·20	·455
18	914	500	7·45 ·45	·23	·55
22 32	987	540	7·15 ·18		
58	1006	550	7·11 ·11	·22	·60

Stat. **44**. 28. May 1910.
28° 37′ N. 19° 8′ W.

LMT	m	f	t °C	S ‰	σ_t
10h 6m	0	0	19·2	36·87	26·415
0	23	13	19·33	·83	·35
7h 55m	46	25	19·26	36·79	26·34
9 53	91	50	18·34	·79	·575
10 30	183	100	16·90	·41	·66
45	274	150	14·94 ·93	·14	·88
59	366	200	13·50 ·49	35·83	·95
8 7	457	250	12·50 ·49	·70	27·055
12 27	549	300	11·27 ·26		
10 14	732	400	9·80 ·79	·43	·335
9 9	914	500	8·27 ·27	·35	·525
12 3	1097	600	7·68 ·68	·43	·68
9 32	1463	800	6·15 ·14	·32	·805
8 31	1829	1000	4·71 ·70	·17	·87

Stat. **46**. 29. May 1910.
28° 56′ N. 21° 45′ W.

LMT	m	f	t °C	S ‰	σ_t
18h 29m	0	0	19·7	37·00	26·385
21 32	23	13	19·74	36·93	·32
18 26	46	25	19·20	·82	·38
21 25	91	50	17·89	·66	·59
17	183	100	17·43	·59	·645
11	274	150	15.26 ·25	·12	·795
3	366	200	13·51 ·50	35·83	·95
20 53	457	250	12·46 ·44	·69	27·05
42	549	300	11·58 ·57	·57	·13
28	732	400	10·06 ·06	·48	·335
10	914	500	8·80 ·80	·51	·57
19 49	1097	600	7·47 ·44	·41	·695
23	1463	800	5·75 ·75	·27	·82
18 51	1829	1000	4·48 ·47	·13	·86

Stat. **49 C**. 2. June 1910.
29° 2′ N. 25° 30′ W.

LMT	m	f	t °C	S ‰	σ_t
8h 21m	23	13	19·56	36·72	26·21
9 28	46	25	19·36	·73	·27
6 24	91	50	18·35	·76	·55
8 14	183	100	17·67	·62	·61
9 20	274	150	16·00		
21	366	200	14·52 ·52	·00	·87
8 56	457	250	12·94 ·93	35·77	27·02
34	549	300	11·93		
35	732	400	10·16 ·14	·47	·31
7h 19m	914	500	8·67 ·67	35·44	27·51
42	1097	600	7·71		
44	1463	800	5·93 ·93	·31	·83
6 44	1829	1000	4·57 ·56	·15	·87
10 21	3950	2160	2·42	34·90	·88
26	4950	2707	2·18 ·45	·90	·87

Stat. **50**. 4. June 1910.
30° 8′ N. 31° 19′ W.

LMT	m	f	t °C	S ‰	σ_t
5h 47m	0	0	20·25	36·81	26·09
6 47	"	"	·30		
7 47	"	"	·40	·81	·05
8 30	23	13	20·38	·78	·035
9 3	46	25	20·12	·87	·17
5 11	91	50	18·26	·56	·42
8 53	183	100	17·66	·52	·54
47	274	150	16·12	·19	·65
40	366	200	15·10 ·08	·05	·78
19	457	250	13·73 ·72	35·85	·92
7 14	549	300	12·34 ·31	·65	27·05
0	732	400	10·52 ·51	·49	·26
5 30	914	500	9·12 ·12	·45	·47
7 55	1097	600	8·14 ·13	·49	·66
6 36	1463	800	6·03 ·03		
1	1829	1000	4·50 ·48	·10	·835

Stat. **51**. 6. June 1910.
31° 20′ N. 34° 56′ W. 3886 metres.

LMT	m	f	t °C	S ‰	σ_t
12h 8m	0	0	20·6	36·61	25·845
25	25	14	20·49	·58	·85
18	50	27	19·38	·57	26·14
3	100	55	18·17	·56	·445
38	200	109	17·04	·33	·54
13 38	300	164	15·90 ·90	·14	·66
12 58	400	219	14·70 ·70	35·94	·78
13 48	"	"	14·67 ·65	·93	·78
14 41	500	273	13·38 ·38	·74	·905
6	600	328	12·00 11·98	·59	27·07
15 1	800	437	9·66 ·66	·41	·35
16 37	1000	547	7·68 ·68		
17 9	1600	875	5·25 ·24	·19	·82
15 41	2000	1094	4·11 ·09	·09	·87

Stat. 53. 9. June 1910.
35° 7′ N. 32° 30′ W. 2865 metres.

LMT	m	f	t °C	S ‰	σ_t
7h 59m	0	0	19·5	36·33	25·925
8 30	23	13	19·30	·23	·90
41	46	25	18·06	·25	26·235
7 59	91	50	16·79	·22	·515
8 58	183	100	15·58 ·57	·09	·70
9 18	274	150	14·06 ·07	35·84	·84
35	366	200	13·04 ·03	·71	·955
56	457	250	12·23 ·22	·60	27·03
8 17	549	300	11·07 ·07	·48	·16
10 27	732	400	9·49 ·48	·36	·345
59	914	500	8·01 ·01	·38	·595
11 41	1200	656	6·85 ·85	·36	·74
12 14	1600	875	4·51 ·49	·08	·82

Stat. 57 (A, B, C, D). 11. June 1910.

A: 37° 7′ N. 29° 41′ W.

LMT	m	f	t °C	S ‰	σ_t
11h 0m	0	0	18·85	36·25	26·05
28	46	25	16·49	·13	·52
10 55	91	50	15·44 ·44	·09	·73
43	457	250	12·20 ·21	35·64	27·06
11 16	914	500	9·15 ·16	·51	·51

B: 37° 9′ N. 29° 40′ W.

LMT	m	f	t °C	S ‰	σ_t
12h 0m	0	0	20·7	36·28	25·57
34	1829	1000	3·94 ·94	35·03	27·84

C: 37° 17′ N. 29° 37′ W.

LMT	m	f	t °C	S ‰	σ_t
14h 0m	0	0	21·75	36·27	25·27
13 49	732	400	10·23 ·22	35·45	27·28

D: 37° 21′ N. 29° 36′ W.

LMT	m	f	t °C	S ‰	σ_t
15h 0m	91	50	15·79 ·77		
14 39	183	100	15·11 ·10	36·06	26·78

Stat. 58. 12. Juni 1910.
37° 37′ N. 29° 25′ W. 948 metres.

LMT	m	f	t °C	S ‰	σ_t
15h 25m	0	0	19·2	36·18	25·89
0	46	25	17·92	·18	26·21
15	91	50	16·06	·16	·64
16h 29m	183	100	14·85 ·85	36·02	26·81
20	457	250	12·37 ·35	35·67	27·06
8	732	400	10·11 ·11	·46	·31

Stat. 59. 17. June 1910.
38° 30′ N. 28° 37′ W. 225 metres.

LMT	m	f	t °C	S ‰	σ_t
16h 34m	0	0	18·9	36·26	26·03
42	23	13	17·64	·19	·29
27	46	25	17·09	·17	·41
18	91	50	15·86 ·86	·10	·63
36	137	75	15·51 ·49	·05	·68
12	180	98	14·97 ·96	·00	·77
5	220	120	14·63 ·63	35·93	·79

Stat. 60. 20 June 1910.
37° 9′ N. 38° 5′ W.

LMT	m	f	t °C	S ‰	σ_t
5h 49m	0	0	19·4	36·26	25·90
6 49	„	„	·8		
7 49	„	„	·8	·25	·78
6 48	23	13	19·56	·21	·82
41	46	25	19·50	·21	·83
8 44	64	38	16·76	·12	26·45
5 53	91	50	16·10	·11	·60
6 55	183	100	15·58 ·58	·07	·68
4	274	150	14·51 ·52	35·89	·78
7 5	366	200	13·65 ·63	·79	·89
8 35	457	250	12·21 ·19	·55	·99
7 17	549	300	10·83 ·82	·37	27·12
8 22	732	400	8·27 ·26	·17	·39
7 57	914	500	6·51 ·52	·16	·63
6 25	1097	600	5·62 ·62	·11	·71
5 32	1554	850	4·08 ·07	·00	·81
4 56	1829	1000	3·67 ·67	34·97	·82

Stat. 63. 22. June 1910.
36° 5′ N. 43° 58′ W.

LMT	m	f	t °C	S ‰	σ_t
9h 49m	0	0	22·2	36·45	25·28
15 49	„	„	·4	·44	·22
10 40	9	5	21·60	·42	·43
32	23	13	19·29	·34	·98
23	46	25	18·34	·36	26·25
10	64	38	17·58	·38	·45
14 15	„	„	·86	·30	·32
16 1	„	„	·73		
9h 58m	91	50	17·39	36·35	26·48
49	183	100	16·71	·27	·57
40	274	150	16·13	·17	·64
15 50	„	„	·16	·20	·66
9 11	366	200	15·23 ·22	35·99	·71
8 35	457	250	13·76 ·76	·73	·82
13 23	„	„	13·74 ·72	·73	·83
15 14	„	„	13·54 ·52	·71	·85
8 47	549	300	12·36 ·35	·54	·96
13 58	640	350	10·13 ·12	·24	27·14
10 51	732	400	8·42 ·41	·11	·32
13 41	„	„	8·41 ·42	·11	·32
15 31	„	„	8·52 ·52	·13	·32
9 26	914	500	5·98 ·97	·16	·71
13 0	1097	600	5·36 ·34	·11	·74
12 36	1463	800	4·21 ·19	34·97	·77
12 4	1829	1000	3·55 ·54	·94	·81
18 53	3000	1640	2·91 ·89	·92	·85
20 44	4000	2187	2·36 ·35	·88	·87
17 20	4850	2652	2·38 ·37		

Stat. 64. 24. June 1910.
34° 48′ N. 47° 52′ W.

LMT	m	f	t °C	S ‰	σ_t
20h 2m	0	0	22·8	36·58	25·21
43	23	13	21·73	·58	·51
37	46	25	19·93	·51	·95
17 17	91	50	17·99	·40	26·37
20 28	183	100	17·40	·34	·46
1	366	200	16·21	·17	·61
19 46	457	250	14·76 ·76		
20 15	540	295	13·09 ·07	35·67	·91
19 27	635	347	11·95 ·93	[·85]	[27·28]
18 52	720	394	10·54 ·54	·34	·15
29	1070	585	5·75 ·74	·05	·64
17 52	1780	973	3·73 ·72	34·95	·80

Stat. 65. 25 June 1910.
37° 12′ N. 48° 30′ W.

LMT	m	f	t °C	S ‰	σ_t
14h 24m	0	0	21·9	36·43	25·35
17 8	23	13	20·85	·36	·60

LMT	m	f	t °C	S ‰	σ_t
16h 58m	46	25	20·01	36·34	25·77
14	91	50	17·20	·31	26·49
20	183	100	16·69		
30	366	200	15·82 ·82	·11	·66
47	540	295	14·04 ·02	35·78	·80
15 0	730	399	10·85 ·84	·35	27·10
14 38	900	492	7·87 ·88		
15 55	1090	596	5·50 ·47		
27	1440	787	4·34 ·33	34·97	·75
14 11	1800	984	3·89 ·87	·96	·79

Stat. **66.** 26.—27. June 1910.
39° 30′ N. 49° 42′ W.

LMT	m	f	t °C	S ‰	σ_t
21h 57m	0	0	19·85	34·57	24·50
23 12	23	13	18·97	35·27	25·27
24	46	25	13·71 ·63	34·83	26·14
0	91	50	10·21 ·20		
40	183	100	8·72 ·69	·85	27·07
0 27	320	175	7·56 ·55	·88	·27
19 57	457	250	6·05 ·03	·92	·51
0 10	545	298	5·47 ·46	·93	·59
22 41	732	400	4·67 ·66	·97	·72
20 25	914	500	4·39 ·38	·98	·76
22 14	1097	600	4·13 ·12	35·00	·79
21 43	1450	793	3·69 ·67	34·94	·79
2	1829	1000	3·50 ·49	·94	·81

Stat. **67** & **67 A.** 27. June 1910.
40° 15′ N. 50° 37′ W.

Stat. **67:**

LMT	m	f	t °C	S ‰	σ_t
10h 14m	0	0	20·6	36·03	25·60
39	91	50	20·06	·40	·83

Stat. **67 A:**

LMT	m	f	t °C	S ‰	σ_t
19h 52m	0	0	21·7	36·18	25·22
18 59	457	250	13·52 ·51	35·73	26·87
19 29	1606	550	4·51 ·48		

Stat. **68.** 28. June 1910.
39° 20′ N. 50° 50′ W.

LMT	m	f	t °C	S ‰	σ_t
10h 6m	0	0	21·5	36·26	25·33
19	46	25	20·81	·27	·53
11	91	50	18·79	·40	26·16
8 34	274	150	17·45	·34	·15
17	457	250	16·34		
7 55	549	300	14·45 ·45		
35	732	400	10·26 ·24	35·28	27·14
8 51	896	490	6·75 ·75	·02	·49
9 25	901	493	6·48 ·48	·02	·53
5 38	905	495	7·20 ·21		
9 53	,,	,,	6·48 ·47	·02	·53
6 2	914	500	6·32 ·32	·02	·54
32	1097	600	4·83 ·81	34·94	·67
7 5	1426	780	4·26 ·23	35·02	·80

Stat. **69.** 29. June 1910.
41° 39′ N. 51° 4′ W.

LMT	m	f	t °C	S ‰	σ_t
6h 0m	0	0	17·15	35·40	25·80
7 0	,,	,,	·10		
35	23	13	16·97	·35	·80
27	46	25	16·48	36·07	26·47
4 6	91	50	15·15 ·15	35·85	·61
7 17	183	100	12·87 ·87	·47	·80
6	274	150	11·54 ·53	·39	27·00
6 54	366	200	9·31 ·31	·16	·21
4 27	457	250	7·52 ·51	·03	·39
6 38	549	300	6·17 ·17	·02	·57
18	732	400	4·47 ·47	34·91	·69
4 47	914	500	4·16 ·16		
5 50	1097	600	3·84 ·82	·92	·76
12	1829	1000	3·35 ·34	·90	·79

Stat. **70.** 30 June 1910.
42° 59′ N. 51° 15′ W. 1100 metres.

LMT	m	f	t °C	S ‰	σ_t
1h 51m	0	0	11·9	32·45	24·65
2 51	,,	,,	·9		
3 51	,,	,,	·9	·57	·74
4 51	,,	,,	·95	·64	·78
4h 51m	9	5	11·77 ·77	32·64	24·92
5 6	18	10	10·89 ·90	·73	25·05
4 59	27	15	8·56 ·56		
5 17	37	20	4·65 ·65	33·04	26·19
1 43	46	25	2·90 ·89	·22	·51
4 44	55	30	4·70 ·70	·74	·74
34	68	37	6·40 ·41	34·16	·86
23	91	50	7·70 ·71	·55	·99
15	179	98	7·86 ·87	·88	27·22
3 54	274	150	6·53 ·55	·91	·43
45	366	200	5·57 ·57	·92	·56
33	457	250	4·61 ·61	·89	·66
1	549	300	4·14 ·14	·91	·72
17	640	350	3·93 ·93	·90	·74
2 44	732	400	3·76 ·77	·90	·755
24	820	448	3·71 ·71	·90	·76
2	914	500	3·71 ·70		

Stat. **70 A.** 30. June 1910.
Ca. 42° 55′ N. 51° 18′ W.

LMT	m	f	t °C	S ‰	σ_t
14h 1m	0	0	12·4	32·45	24·56
21	9	5	11·76 ·76	·43	·67
14	18	10	11·15 ·15	·41	·78
8	27	15	8·25 ·26	·67	25·44
13 29	37	20	4·12 ·11	·86	26·10
19	46	25	4·22 ·22	33·40	·52
37	54	30	4·20 ·19	·54	·63
41	68	37	5·64 ·64	·94	·78
52	95	52	6·97 ·97	34·39	·96
14 31	185	101	7·94 ·94	·87	27·20

Stat. **71.** 30. June 1910.
43° 18′ N. 51° 17′ W.

LMT	m	f	t °C	S ‰	σ_t
21h 59m	0	0	12·2	32·61	24·71
56	18	10	11·71 ·71	·84	·99
22 2	27	15	9·28 ·29	33·05	25·57

LMT	m	f	t °C	S ‰	σ_t
21 49	37	20	5·18 ·18	33·52	26·51
34	46	25	5·40 ·40	·79	·70
42	69	38	6·79 ·82	34·30	·92
24	91	50	7·00 ·01	·43	·99
14	134	73	7·34 ·35	·54	27·03

Stat. **72.** 1. July 1910.
44° 35′ N. 51° 15′ W. 72 metres.

LMT	m	f	t °C	S ‰	σ_t
5h 2m	0	0	10·7	32·20	24·67
6 2	„	„	·55	·20	·70
3	9	5	10·43 ·44	·20	·72
5 56	18	10	10·42 ·42	·21	·73
44	27	15	9·56 ·57	·23	·89
6 25	32	18	5·35 ·34	·45	25·64
5 37	37	20	2·27 ·28		
27	46	25	2·03 ·03	·74	26·18
6 12	55	30	2·02 ·02		
14	70	38	2·03 ·03	·79	·23

Stat. **73.** 1. July 1910.
45° 58′ N. 51° 25′ W. 70 metres.

LMT	m	f	t °C	S ‰	σ_t
21h 1m	0	0	8·45	32·07	24·93
33	9	5	8·20 ·21	·21	25·08
23	18	10	7·87 ·89	·19	·11
20 56	27	15	7·08 ·09	·25	·27
21 16	32	18	6·53 ·55	·34	·40
5	37	20	1·59 ·59	·60	26·10
20 50	46	25	0·51 ·51		
39	64	35	- 0·10 - ·10	·90	·43

Stat. **74.** 2. July 1910.
47° 25′ N. 52° 20′ W. 156 metres.

LMT	m	f	t °C	S ‰	σ_t
18h 9m	0	0	7·2	32·25	25·25
23	27	15	6·17 ·19	·28	·40
17 56	37	20	4·76 ·75		
18 3	46	25	0·63 ·63	·55	26·12
16	91	50	- 1·52 - ·52	·88	·47
9	146	80	- 1·00 - ·00	33·14	·67

Stat. **75.** 9. July 1910.
47° 22′ N. 49° 16′ W. 120 metres.

LMT	m	f	t °C	S ‰	σ_t
6h 16m	0	0	6·3	32·39	25·48
32	18	10	6·11 ·12		
24	27	15	5·74 ·75		
5 43	37	20	2·46 ·48		
50	46	25	- 0·57 - ·58		
6 17	55	30	- 1·43 - ·42		
5 58	64	35	- 1·35 - ·36		
6 8	73	40	- 1·10 - ·10		
6 39	91	50	- 1·06 - ·06		
5 30	118	65	- 0·87 - ·87		

Stat. **76.** 9. July 1910.
47° 11′ N. 47° 6′ W.

LMT	m	f	t °C	S ‰	σ_t
18h 21m	0	0	5·9	32·89	25·91
19 21	„	„	·9	·87	·90
20 21	„	„	·85	·88	·91
19 31	18	10	4·72 ·71	·98	26·13
25	37	20	3·07 ·08		
18 57	46	25	0·87 ·89	33·60	·945
19 7	55	30	- 0·35 - ·34	·69	27·085
18	64	35	- 0·16 - ·15	·86	·205
18 36	91	50	0·92 ·93	34·13	·365
28	137	75	1·92 ·93	·42	·525
18	183	100	2·69 ·70	·57	·59
7	274	150	3·28 ·29		
17 45	366	200	3·37 ·38	·80	·715

Stat. **77.** 10. July 1910.
47° 18′ N. 44° 54′ W. 171 metres.

LMT	m	f	t °C	S ‰	σ_t
14h 40m	0	0	8·1	33·21	25·89
15 33	„	„	·45	·23	·85
16 33	„	„	9·5	·22	·67
2	9	5	7·75 ·75	·20	·92
15 47	18	10	7·50 ·52	·21	·96
54	37	20	6·77 ·79	·34	26·16
14 46	46	25	3·90 ·84	·58	·70
15h 23m	55	30	2·30 ·30	33·95	27·125
32	73	40	2·47 ·48	34·10	·23
14 54	91	50	2·20 ·22	·17	·315
15 40	114	63	2·45 ·46	·335	·425
15	137	75	3·13 ·15	·51	·495
3	165	90	3·43 ·46	·56	·51

Stat. **79.** 10 July 1910.
47° 16′ N. 44° 17′ W. 271 metres.

LMT	m	f	t °C	S ‰	σ_t
20h 36m	0	0	9·2	33·30	25·77
21 27	9	5	7·96 ·99	·35	26·00
20	27	15	6·17 ·17	·63	·48
13	37	20	4·00 3·98	·79	·85
20 14	55	30	2·82 ·82	34·09	27·20
21 6	73	40	2·77 ·78	·23	·32
20 57	91	50	2·71 ·72	·31	·38
22	137	75	2·43 ·44	·44	·51
49	183	100	2·80 ·81	·56	·58
38	265	145	2·82 ·83	·81	·78

Stat. **80.** 11. July 1910.
47° 34′ N. 43° 11′ W.

LMT	m	f	t °C	S ‰	σ_t
5h 40m	0	0	11·8	34·24	26·06
6 40	„	„	·8	·24	·06
35	23	13	11·84 ·84	·29	·09
18	46	25	11·65 ·68	·61	·37
5 42	91	50	9·63 ·63	35.02	27·05
10 13	137	75	7·24 ·25	34·67	·15
5 10	180	98	7·58 ·59	.82	·22
6 5	274	150	4·81 ·82	·72	·50
5 52	366	200	4·99 ·99	·91	·63
9 18	457	250	4·62 ·62	·94	·69
8 22	549	300	4·52 ·51	·98	·74
7	732	400	3·32 ·31	·86	·76
9 0	914	500	3·30 ·30	·87	·77
8 39	1097	600	3·28 ·28	·89	·79

Stat. 81. 12. July 1910.
48° 2′ N. 39° 55′ W.

LMT	m	f	t °C	S ‰	σt
10h 19m	0	0	14·8	35·53	26·44
11 19	,,	,,	15·2		
0	46	25	14·72 ·71	·70	·60
10 6	91	50	14·07 ·06		
11 22	183	100	12·93 ·93	·67	·94
9 57	274	150	12·86 ·86	·72	27·00
44	457	250	11·62 ·62	·54	·10
10 50	549	300	9·46 ·46	·16	·19
11 11	640	350	7·86 ·86	34·99	·31
10 36	732	400	6·46 ·47	·89	·43
21	914	500	5·07 ·05	·92	·63

Stat. 81 A. 12. July 1910.
48° 1′ N 39° 46′ W.

LMT	m	f	t °C	S ‰	σt
20h 5m	0	0	15·1	35·40	26·28
50	46	25	14·33 ·33	·65	·64
41	183	100	12·50 ·49	·51	·91
31	457	250	9·45 ·45	·14	27·18
16	914	500	4·54 ·53	34·89	·66
19 57	1097	600	3·99 ·98	·92	·75
25	1701	930	3·69 ·68	·95	·80

Stat. 82. 13. July 1910.
48° 26′ N. 37° 0′ W.

LMT	m	f	t °C	S ‰	σt
21h 17m	0	0	15·4	35·28	26·12
16	46	25	14·33 ·35	·53	·55
27	91	50	12·86 ·85	·44	·78
23 45	137	75	12·87 ·89	·58	·89
21 41	183	100	12·80 ·80	·70	·99
55	366	200	11·21 ·21	·42	27·08
22 11	549	300	8·02 ·01	34·98	·28
30	732	400	5·77 ·77	·92	·54
52	914	500	4·72 ·71		
23 22	1189(?)	650(?)	4·13 ·11	·95	·76

Stat. 83. 14. July 1910.
48° 30′ N. 33° 55′ W.

LMT	m	f	t °C	S ‰	σt
16h 20m	0	0	16·0	35·61	26·24
17 18	,,	,,	15·6		
16 47	23	13	15·97 ·99		
29	46	25	14·82 ·81	·55	·46
37	69	38	12·53 ·52	·58	·96
6	91	50	12·09 ·08	·54	27·01
53	183	100	11·35 ·35	·49	·11
23 6	270	147	11·11 ·11	·44	·12
17 3	366	200	10·01 ·01	·28	·19
22 50	450	246	8·84 ·84		
17 54	457	250	8·31 ·32	·05	·29
15	549	300	7·10 ·10	34·95	·38
39	732	400	5·18 ·17	·88	·58
21 28	914	500	4·53 ·53	·95	·71
49	1097	600	4·11 ·11	·93	·74
22 22	1692	925	3·42 ·42	·90	·79

Stat. 85. 15.—16. July 1910.
47° 58′ N. 31° 41′ W.

LMT	m	f	t °C	S ‰	σt
22h 9m	0	0	16·4	35·64	26·165
23 9	,,	,,	·4	·67	·19
22 15	18	10	16·37	·66	·19
28	46	25	16·00 ·00	·65	·26
47	69	37	14·43 ·42	·57	·56
38	91	50	12·38 ·37	·58	·99
23 9	183	100	11·22 ·21	·41	27·08
19	274	150	10·72 ·71	·38	·15
0 9	366	200	9·93 ·92	·26	·20
22 58	457	250	8·37 ·38	·01	·25
0 23	549	300	6·87 ·87	34·88	·36
40	732	400	5·37 ·35	·89	·57
1 53	914	500	4·63 ·60	·97	·72
20	1372	750	3·71 ·69	·91	·77
23 40	1692	925	3·38 ·37	·80	·72

Stat. 86. 16. July 1910.
47° 29′ N. 30° 20′ W.

LMT	m	f	t °C	S ‰	σt
18h 14m	0	0	18·25	36·01	26·00
37	46	25	16·29	·08	·52
17 42	91	50	14·85 ·86	35·95	·75
20 7	183	100	13·40 ·39	·80	·95
19 45	274	150	12·56 ·56	·65	27·01
20 44	366	200	11·85 ·83	·56	·08
17 55	457	250	10·96 ·97	·42	·12
19 56	549	300	10·61 ·60	·38	·17
18 28	732	400	9·01 ·01	·34	·40
12	914	500	6·27 ·27	·10	·62

Stat. 87. 17. July 1910.
46° 48′ N. 27° 44′ W. 2157 metres.

LMT	m	f	t °C	S ‰	σt
18h 6m	0	0	18·75		
23	23	13	17·29	35·705	26·01
31	46	25	13·37 ·35	·705	·89
41	91	50	12·70 ·70	·68	27·00
55	183	100	12·16 ·14	·60	·05
19 4	274	150	11·56 ·54	·53	·11
53	549	300	10·51 ·50	·36	·17
37	732	400	8·12 ·12	·14	·39
17	914	500	6·46 ·48	·07	·57
20 13	1463	800	4·01 ·01	34·98	·80

Stat. 88. 18. July 1910.
45° 26′ N. 25° 55′ W. 3120 metres.

LMT	m	f	t °C	S ‰	σt
12h 14m	0	0	19·1	35·78	25·61
12	91	50	13·41	·78	26·94
33	366	200		·53	

Stat. 88 A. 18. July 1910.
45° 12′ N. 25° 46′ W.

LMT	m	f	t °C	S ‰	σt
18h 7m	0	0	18·9	35·80	25·67
19 7	,,	,,	18·6		
18 21	46	25	15·40	·84	26·54
27	69	38		·82	
17 59	88	48	13·67	·81	·90
19 21	91	50		·79	
30	183	100	12·57	·73	27·07
43	274	150		·59	

LMT	m	f	t °C	S ‰	σ_t
20 50	457	250	10·77	35·41	27·16
21 52	563	308	·26	·41	·25
9	732	400	8·86	·22	·34
31	915	500	7·14	·20	·58
22 17	1427	780	4·37	34·97	·75

Stat. 88 B. 19. July 1910.
45° 28′ N. 25° 24′ W.

LMT	m	f	t °C	S ‰	σ_t
11h 8m	0	0	19·25		
12 8	„	„	·6	35·83	25·52
11 39	457	250	10·91	·44	27·15
10 56	914	500	8·06	·35	·56
11 19	1097	600	7·02	·30	·68
10 31	1463	800	4·48	·01	·77

Stat. 89. 20 July 1910.
45° 55′ N. 22° 24′ W.

LMT	m	f	t °C	S ‰	σ_t
4h 22m	0	0	19·15	35·87	25·665
7	46	25	14·46	·77	26·70
16	91	50	13·03	·74	·98
24	183	100	12·22	·61	27·04
35	366	200	11·05	·48	·16
49	549	300	10·20	·42	·27
5 6	732	400	9·16		
51	823	450	8·25	·35	·54
30	914	500		·26	
6 12	1006	550	6·51	·21	·67

Stat. 90. 21 July 1910.
46° 58′ N. 19° 6′ W.

LMT	m	f	t °C	S ‰	σ_t
10h 15m	0	0	17·85	35·61	25·79
11 15	„	„	·6		
10 23	23	13	16·66	·61	26·08
30	46	25	12·73	·64	·96
38	91	50	11·95	·61	27·09
47	183	100	·40	·54	·14
11 52	366	200	10·96		
40	549	300	·51	·44	·23
23	732	400	9·98	·41	·30
3	914	500	8·90	·44	·50
13 5	1097	600	7·98	·44	·64
12 24	1463	800	5·19	·11	·76

Stat. 91. 22. July 1910.
47° 32′ N 16° 38′ W. 4922 metres.

LMT	m	f	t °C	S ‰	σ_t
11h 25m	0	0	16·55	35·51	26·03
12 45	„	„	·65		
1	23	13	15·33	·51	·31
17	37	20	14·56		
10	46	25	12·69	·51	·86
11 31	91	50	11·05	·51	27·18
20 15	549	300	[8·66]	·36	[·48]
19 54	732	400	8·64	·35	·47
11 48	914	500	7·87		
19 23	1097	600	5·96		
13 25	1463	800	4·34		
20 17	2000	1094	3·52		
17 50	3500	1914	2·63 ·63	34·965	27·91
14 40	4000	2187	2·56 ·57		
17 55	4750	2597	2·27	·915	·91

Stat. 92. 23. July 1910.
48° 29′ N. 13° 55′ W.

LMT	m	f	t °C	S ‰	σ_t
12h 17m	0	0	16·4	35·57	26·11
13 2	„	„	·45		
14 17	„	„	·55		
8	23	13	·39	·54	·10
16	37	20	12·79	·53	·87
1	46	25	·24	·54	·98
13 54	91	50	11·13	·51	27·17
11 47	183	100	10·84	·49	·21
18	366	200	·32	·45	·27
58	457	250	·15	·42	·28
4	549	300	9·84		
15 55	640	350	·46	·39	·37
12 15	732	400	·08	·43	·43
16 15	823	450	8·61	·45	·56
14 30	914	500	·46	·53	·64
12 39	1006	550	7·13	·34	·69
15 33	„	„	·08	·32	·68
5	1097	600	6·93	·35	·73
13 3	1189	650	5·98	·22	·75
34	1518	830	4·04	34·97	·78

Stat. 93. 25. July 1910.
50° 3′ N. 11° 23′ W. 1257 metres.

LMT	m	f	t °C	S ‰	σ_t
16h 9m	0	0	15·15	35·50	26·34
17 24	„	„	·1		
	5	3		·46	
16 49	23	13	·07	·46	·33
42	37	20	14·39	·46	·48
35	46	25	12·09	·44	·93
19 31	69	38	10·87	·49	27·20
18 46	91	50	·77	·49	·22
54	183	100	·42	·42	·23
19 4	366	200	·26		
17	457	250	·13	·43	·29
18 23	549	300	9·95	·43	·32
8	732	400	·21	·42	·43
17 50	914	500	8·63	·47	·57
29	1006	550	·20	·47	·64
7	1097	600	7·415	·40	·70

Stat. 96. 27. July 1910.
50° 50′ N. 10° 55′ W. 184 metres.

LMT	m	f	t °C	S ‰	σ_t
13h 46m	0	0	15·1	35·22	26·14
42	5	3		·22	
40	9	5		·21	
37	23	13		·23	
34	46	25		·23	
30	91	50		·43	
25	137	75		·42	
20	178	98		·42	

Stat. 97. 4 August 1910.
56° 15′ N. 8° 28′ W. 139 metres.

LMT	m	f	t °C	S ‰	σ_t
17h 51m	0	0	13·55	34·88	26·20
18 51	„	„	·4		
19 3	10	6	13·28* ·27	·95	·32
18 53	25	14	11·85* ·92	35·16	·75
15	50	28	9·37* ·38	·28	27·30
42	75	41	8·84* ·84	·25	·36
29	100	55	8·60* ·61	·20	·36

Stat. 98. 5. August 1910.
56° 33′ N. 9° 30′ W.

LMT	m	f	t °C	S ‰	σ_t
9h 40m	0	0	14·35	35·23	26·31
10 39	25	14	13·01* ·03	·29	·63
17	50	28	10·88* ·91	·37	27·10
31	100	55	9·86* ·89	·34	·26
9 59	200	110	9·40* ·42	·35	·35
45	400	219	9·20* ·21	·34	·37
8 13	500	273	9·06* ·07	·33	·39
9 26	600	328	8·81* ·82	·33	·42
6	800	437	8·18* ·18	·27	·48
8 40	1000	547	7·14* ·14	·20	·58

Stat. 99. 6 August 1910.
57° 45′ N. 13° 40′ W. 149 metres.

LMT	m	f	t °C	S ‰	σ_t
9h 44m	0	0	12·45	35·24	26·71
39	25	14	11·99* 12·01	·27	·82
30	50	28	10·76* ·78	·28	27·05
49	75	41	8·75* ·76	·27	·39
19	100	55	8·54* ·57	·29	·43
4	130	71	8·48* ·49	·29	·45

Stat. 100. 6. August 1910.
57° 48′ N. 12° 43′ W. 1530 metres.

LMT	m	f	t °C	S ‰	σ_t
15h 48m	0	0	13·2	35·27	26·58
16 48	„	„	·15		
15 5	25	14	12·86* ·90	·35	·70
17 34	50	28	10·71* ·72	·31	27·08

LMT	m	f	t °C	S ‰	σ_t
17h 24m	100	55	9·53* ·55		
12	200	110	9·01* ·02	35·32	27·38
16 59	400	219	8·46* ·47	·28	·44
44	590	322	8·18* ·17	·26	·47
26	800	437	7·48* ·48	·20	·53
15 30	1000	547	6·53* ·53	·17	·63
56	1185	648	5·27* ·22	·05	·70
17 57	1400	765	4·49*	·01	·76

Stat. **101.** 7. August 1910.
57° 41′ N. 11° 48′ W. 1853 metres.

LMT	m	f	t °C	S ‰	σ_t
0h 52m	0	0	13·4		
1 52	"	"	13·4	35·32	26·57
47	50	28	10·34* ·36	·35	27·19
2 4	100	55	9·53* ·54	·33	·30
20	200	110	9·09* ·11	·31	·39
39	400	219	8·73* ·73	·31	·42
1 31	600	328	8·43* ·43	·27	·44
0 37	1000	547	6·93* ·92	·20	·61
1 5	1400	765	4·63* ·59	·02	·76
0 0	1750	957	3·51	34·98	·84

Stat. **103.** 10. August 1910.
60° 26′ N. 2° 34′ W. 159 metres.

LMT	m	f	t °C	S ‰	σ_t
12h 30m	0	0	13·15	31·98	26·30
27	10	6	13·19* ·20	35·08	·43
19	25	14	12.24* ·26	·22	·73
1	50	28	9·58* ·62	·29	·26
11	75	41	9·08* ·10	·28	·34
11 53	100	55	8·64* ·64	·28	·41
42	150	82	8·60* ·60	·29	·43

Stat. **104.** 10. August 1910.
60° 35′ N. 3° 20′ W. 234 metres.

LMT	m	f	t °C	S ‰	σ_t
15h 47m	0	0	13·3	35·21	26·51
14 51	25	14	12·15* ·17	·26	·78
15 45	35	19	11·48* ·51	·27	·91
38	50	28	9·86* ·89	·34	27·26
15 30	75	41	9·49* ·50	35·36	27·34
21	100	55	9·33* ·35	·34	·35
11	150	82	9·14* ·16	·34	·38
2	200	110	9·09* ·10	·34	·39

Stat. **105.** 10. August 1910.
60° 45′ N. 3° 50′ W. 670 metres.

LMT	m	f	t °C	S ‰	σ_t
19h 45m	0	0	12·75	35·17	26·59
20 5	25	14	11·37* ·40	·17	·85
19 57	50	28	9·86* ·91	·17	27·12
48	75	41	9·07* ·10	·17	·25
40	100	55	8·20* ·21	·17	·39
18 16	200	110	7·38* ·39	·18	·53
20 13	"	"	7·61* ·58	·18	·49
19 30	300	164	7·08* ·09	·17	·56
19	400	219	5·59* ·59	·07	·68
7	500	273	2·79* ·75	34·90	·85
18 52	600	328	0·65* ·62	·89	28·00
33	650	355	0·17* ·16	·89	·02

Stat. **106.** 10. and 11. August 1910.
60° 54′ N. 4° 28′ W. 1140 metres.

LMT	m	f	t °C	S ‰	σ_t
22h 42m	0	0	13·05	35·00	26·40
23 16	25	14	11·50* ·52		
7	50	28	9·58* ·62	·31	27·28
22 55	75	41	9·12 ·14	·33	·37
45	100	55	9·10* ·10	·33	·38
1 20	200	110	8·82* ·83	·30	·40
32	300	164	8·61* ·61	·29	·42
0 8	400	219	8·33* ·33	·26	·44
48	500	273	7·39* ·39	·17	·52
23 30	600	328	4·74* ·75	·05	·76
1 5	700	383	1·53* ·51	34·86	·91
23 50	800	437	0·11* ·09	·89	28·03
1 50	1000	547	0·63	·90	·08
0 28	1100	601	0·79* ·82	·90	·09

Stat. **107.** 11. August 1910.
61° 4′ N. 5° 5′ W. 730 metres.

LMT	m	f	t °C	S ‰	σ_t
4h 50m	0	0	12·0	35·28	26·82
47	25	14	11·67* ·73	·25	·86
5 0	50	28	9·96* 10·00	·25	27·17
11	75	41	9·20* ·22	·25	·30
22	100	55	8·71* ·73	·21	·34
6 52	200	110	7·86* ·88	·22	·48
41	300	164	6·83* ·83	·16	·58
29	400	219	5·41* ·39	·08	·71
15	500	273	1·87* ·84	34·88	·90
5 58	600	328	0·14* ·12	·89	28·03
40	700	383	0·50* ·52	·91	·08

Stat. **108.** 11. August 1910.
61° 13′ N. 5° 47′ W. 249 metres.

LMT	m	f	t °C	S ‰	σ_t
9h 37m	0	0	11·9	35·24	26·81
17	25	14	11·37* ·54	·20	·86
44	50	28	10·54* ·53	·20	27·03
10 34	75	41	9·58* ·59	·21	·20
24	100	55	8·52* ·54	·28	·43
16	150	82	7·89* ·90	·21	·47
9 32	190	104	7·85* ·84	·20	·47
55	200	110	7·12* ·14	·16	·54
10 5	245	134	6·97* ·97	·16	·57

Stat. **109.** 11. August 1910.
61° 22′ N. 6° 24′ W. 228 metres.

LMT	m	f	t °C	S ‰	σ_t
13h 34m	0	0	10·85	35·17	26·95
11	25	14	9·73 ·80	·10	27·09
18	50	28	8·89* ·91	·15	·27
26	75	41	8·29* ·34	·16	·37
35	100	55	8·28* ·30	·15	·37
41	150	82	8·28* ·29	·16	·38
51	200	110	7·95* ·95	·14	·41

Stat. **110**. 11. August 1910.
61° 39′ N. 5° 57′ W. 170 metres.

LMT	m	f	t °C	S ‰	σ_t
23h 36m	0	0	11·05	35·15	26·90
55	25	14	10·51* ·55	·16	27·00
44	50	28	9·48* ·50	·17	·19
32	85?	47?	8·37* ·40	·16	·36
23	100	55	7·82* ·84	·16	·44
12	150	82	7·59* ·61	·16	·48

Stat. **111**. 12. August 1910.
61° 32′ N. 5° 16′ W. 300 metres.

LMT	m	f	t °C	S ‰	σ_t
3h 39m	0	0	11·75	35·19	26·80
4 17	10	6	11·18* ·26	·17	·88
7	25	14	9·82* ·86	·16	27·12
3 57	50	28	8·69* ·71	·17	·32
48	75	41	8·17* ·18	·18	·41
37	100	55	7·58* ·58	·16	·48
26	150	82	6·94* ·96	·12	·54
14	200	110	6·45* ·46	·12	·61
0	275	150	6·20* ·19	·12	·64

Stat. **112**. 12. August 1910.
61° 24′ N. 4° 34′ W. 560 metres.

LMT	m	f	t °C	S ‰	σ_t
7h 42m	0	0	11·30	35·17	26·87
42	25	14	10·27* ·32	·17	27·05
52	50	28	9·28* ·30	·21	·25
8 2	75	41	8·18* ·20	·19	·41
7 23	100	55	7·89*	·19	·46
8 13	150	82	7·68* ·68	·21	·50
29	200	110	7·54* ·55	·20	·52
41	300	164	7·07* ·08	·15	·55
53	400	219	6·28* ·29	·12	·63
9 10	450	246	4·51*	34·98	·74
25	500	273	1·10* ·08	·88	·96

Stat. **113**. 12. August 1910.
61° 16′ N. 3° 50′ W. 1080 metres.

LMT	m	f	t °C	S ‰	σ_t
12h 45m	0	0	11·65	35·20	26·83
11	25	14	10·39* ·43	·19	27·05
21	50	28	9·00* ·01	·19	·29
31	75	41	8·44* ·45	·19	·37
16 43	100	55	8·35*	·19	·39
57	200	110	7·43* ·43	·17	·51
17 11	300	164	6·44* ·45	·09	·58
16 16	400	219	3·75* 4·12	·00	·81
30	500	273	1·12*	34·83	·92
14 53	600	328	0·20* ·17	·91	28·04
17 27	800	437	0·50* ·53	·90	·07

Stat. **114**. 12. and 13. August 1910.
61° 8′ N. 3° 14′ W. 1047 metres.

LMT	m	f	t °C	S ‰	σ_t
23h 47m	0	0	12·35	35·17	26·67
20	25	14	10·59* ·63	·18	27·00
30	50	28	8·37* ·39	·17	·37
41	100	55	7·48* ·50	·16	·49
53	200	110	6·79* ·80	·16	·59
0 15	300	164	5·27* ·26	·07	·72
1 24	350	191	3·29* ·26	34·91	·81
0 40	400	219	2·07* ·04	·84	·86
1 11	450	246	1·11* ·11	·85	·93
0 51	500	273	0·82*	·85	·95
2 9	800	437	0·48* ·50	·89	28·06
1 47	1000	547	0·83* ·87	·89	·08

Stat. **115**. 13. and 14. August 1910.
61° 0′ N. 2° 41′ W. 580 metres.

LMT	m	f	t °C	S ‰	σ_t
13. aug.:					
5h 50m	0	0	12·45	35·20	26·67
6 50	„	„	·45	·20	·67
7 50	„	„	·45	·20	·67
9 10	„	„	·6	·19	·64
9 50	„	„	·65	·17	·61
10 50	„	„	·7	·21	·63
12 0	„	„	·75	·24	·64
13h 50m	0	0	12·75	35·22	26·63
14 50	„	„	·55	·19	·65
16 0	„	„	·65	·22	·65
50	„	„	·55	·17	·63
17 50	„	„	·55	·17	·63
18 50	„	„	·6	·25	·68
19 50	„	„	·55	·21	·66
20 50	„	„	·55		
21 50	„	„	·65	·22	·65
22 50	„	„	·65	·22	·65
23 50	„	„	·55	·20	·65
14. aug.:					
0h 50m	„	„	·55	·20	·65
1 50	„	„	·45	·09	·59
2 50	„	„	·55	·13	·60
3 50	„	„	·65	·15	·59
4 50	„	„	·7	·14	·58
6 50	„	„	·75	·17	·59
13. aug.:					
10h 44m	25	14	10·19* ·21	·15	27·05
8 22	50	27	9·16* ·10	·15	·23
12	100	55	[8·10*] 7·77	·18	·47
32	„	„	7·79* ·79	·19	·47
10 53	„	„	7·90* ·90	·18	·45
13 41	100	55	7·90* ·93	[35·34]	[27·57]
16 18	„	„	7·67* 67	·18	·48
18 13	„	„	7·67* ·67	·15	·46
20 39	„	„	7·63* ·53	·18	·49
22 50	„	„	7·67* ·67	·19	·49
14. aug.:					
1h 38m	„	„	7·74* ·75	·18	·48
4 10	„	„	7·67* ·68	·18	·48
13. aug.:					
7h 15m	200	109	6·88* ·89	·17	·59
11 6	„	„	7·03* ·04	·15	·55
13 41	„	„	6·88* ·89	·14	·56
14 51	„	„	6·88* ·89	·14	·56
16 43	„	„	6·98* 7·09	·12	·53
18 25	„	„	6·73* ·73	·13	·58
20 28	„	„	6·88* ·87	·13	·56
23 37	„	„	6·68* ·72	·16	·60

LMT	m	f	t °C	S ‰	σ_t
14. aug.:					
2h 25m	200	109	7·08* ·08	35·13	27·53
4 24	-	„	6·88* ·90	·17	·59
13. aug.:					
20h 17m	250	137	6·28* ·30	·10	·61
6 55	300	164	5·38* ·34	·08	·72
7 57	„	„	4·77* ·78	·05	·76
10 17	„	„	4·94* ·94	·02	·72
11 40	„	„	5·22* ·22	·02	·68
13 28	„	„	5·52* ·54	·08	·69
14 26	„	„	5·41* ·44	·05	·68
15 4	„	„	5·46* ·46	·11	·73
16 58	„	„	5·59* ·59	·11	·71
18 2	„	„	4·85* ·86		
43	„	„	4·76* ·76	·04	·75
19 50	„	„	4·83* ·84		
21 42	„	„	5·06* ·07		
23 10	„	„	4·88* ·88		
14. aug.:					
0h 15m	„	„	4·73* ·73	35·03	27·75
1 25	„	„	4·94* ·94	34·99	·69
2h 42m	300	164	5·46* ·46	35·07	27·70
3 42	„	„	5·41* ·45	·08	·71
4 38	„	„	5·48* ·50	·06	·68
5 28	„	„	5·15* ·17	·01	·68
13. aug.:					
20h 6m	350	191	3·55* ·56	34·94	·80
9 24	390	213	2·43* ·38	·87	·85
6 40	400	219	2·51* ·48	·88	·85
9 50	„	„	2·31* ·33	·87	·86
11 26	„	„	2·33* ·31	·87	·86
13 53	„	„	2·34* ·28	·85	·85
15 50	„	„	2·51* ·49	·86	·84
17 32	„	„	2·41* ·39	·89	·87
21 8	„	„	2·32* ·30		
23 52	„	„	2·51* ·51	·92	·88
14. aug.:					
3h 4m	„	„	2·61* ·63		
4 52	„	„	2·61* ·58		
13. aug.:					
6h 21m	500	273	0·77* ·76	·89	·99
7 42	„	„	0·79* ·73	·87	·97
10h 31m	500	273	0·85* ·83	34·86	27·96
12 23	„	„	0·90* ·89	·87	·97
14 11	„	„	0·77* ·75	·85	·95
16 4	„	„	0·77* ·75	·85	·95
17 47	„	„	0·76* ·75	·90	28·00
22 20	„	„	0·88* ·84	·90	·00
14. aug.:					
1h 4m	„	„	0·75* ·73	·89	·00
3 22	„	„	0·93* ·82	·84	27·94
5 9	„	„	0·95* ·93		
13. aug.:					
6h 0m	550	301	0·55* ·53	·89	28·01

Stat. **116**. 14. August 1910. 60° 52′ N. 2° 1′ W. 125 metres.

LMT	m	f	t °C	S ‰	σ_t
9h 52m	0	0	12·6	35·12	26·58
10 5	25	14	11·96* ·93	·25	·81
14	35	19	10·63* ·75	·26	27·05
9 55	50	28	9·86* ·88	·33	·25
46	75	41	9·17* ·18	·34	·37
38	100	55	8·88* ·90	·33	·41

Table III. Physical Conditions at Standard Depths.

Numerical Value of Argument *a*	*a* = *m*, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	*a* = *D*, Dynamic Metres: Density *in situ* σ_t, D	Pressure Decibars	*a* = *p*, Pressure (Decibars): Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
Stat. 1. 9. April 1910. 49° 27′ N., 8° 36′ W. 146 m.								
0	10·1	35·37	27·24	+ 604	27·24	0·0000	0·97349	0·0000
10	9·75	·37	·30	+ 108	·35	10·2720	·97338	9·7313
25	·61	·36	·32	+ 9	·43	25·6839	·97331	24·3315
50	·60	·36	·32	+ 9	·56	51·3713	·97319	48·6657
75	·59	·36	·32	+ 9	·67	77·0617	·97309	72·9941
100	·58	·36	·32		·79	102·7550	·97298	97·3199
Stat. 2. 10. April 1910. 49° 30′ N., 9° 42′ W. 149 m.								
0	9·6	35·25	27·23	+422	27·23	0·0000	0·97349	0·0000
10	·35	·25	·27	+115	·32	10·2728	·97341	9·7345
25	·20	·24	·29	+ 59	·40	25·6832	·97334	24·3351
50	·16	·25	·30	+ 15	·54	51·3700	·97321	48·6669
75	·14	·25	·31	+ 9	·66	77·0601	·97310	72·9957
100	·13	·25	·31	14	·78	102·7531	·97299	97·3218
150	·13	·24	·30		28·01	154·148	·97278	145·966

Numerical Value of Argument a	a = m, Common Metres				a = D, Dynamic Metres		a = p, Pressure (Decibars)	
	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³/ton	Depth of Isobaric Surfaces Dynamic Metres

Stat. **3**. 10. April 1910. 49° 32′ N. 10° 49′ W. 184 m.

0	10·4	35·49	27·28	+190	27·28	0·0000	0·97345	0·0000
10	·25	·48	·30	− 3	·35	10·2732	·97338	9·7342
25	·21	·47	·30	+ 2	·41	25·6830	,97333	24·3344
50	·21	·47	·30	+ 30	·54	51·3708	·97321	48·6661
75	·17	·47	·31	+ 23	·66	77·0609	·97310	72·9949
100	·14	·47	·31	− 30	·78	102·7539	·97299	97·3210
150	.23	·47	·30		28·00	154·149	·97278	145·965

Stat. **4 (A & B)**. 10. April 1910. 49° 30′ N. 11° 40′ W.

0	10·6	35·52	27.27	−166	27·27	0·0000	0·97346	0·0000
10	·52	·48	·25	− 42	·30	10·2729	·97343	9·7344
25	·47	·46	·24	+ 93	·35	25·6828	,97338	24·3355
50	·43	·48	·27	+ 57	·51	51·3686	·97324	48·6682
75	·44	·50	·28	+ 17	·63	77·0579	·97313	72·9978
100	·42	·50	·28	+ 7	·75	102·7502	·97302	97·3246
150	·32	·48	·29	+ 12	·99	154·144	·97279	145·970
200	·25	·47	·29	+ 2	28.22	205·549	·97258	194·604
300	·25	·47	·29	+ 4	·69	308·395	·97216	291·841
400	·20	·46	·29	+ 31	29·15	411·287	·97173	389·036
500	·00	·45	·32	+ 76	·64	514·227	·97127	486·186
600	9·68	·47	·39	+ 85	30·19	617·219	·97078	583·288
700	·35	·50	·47	+ 47	·73	720·265	·97029	680·341
800	·23	·53	·51		31·24	823·363	·96982	777·346

Stat. **5**. 16. April 1910. 51° 24′ N. 9° 27′ W. 68 m.

0	8·4	34·66	26·96	+157	26·96	0·0000	0·97375	0·0000
10	·35	·67	·98	+ 53	27·03	10·2700	·97368	9·7371
25	·30	·67	·99	+453	·10	25·6760	·97362	24·3118
50	·28	·81	27·10		·34	51·3565	·97340	48·6795

Stat. **6**. 16. April 1910. 50° 33′ N. 10° 42′ W. 168 m.

0	9·9	35·43	27·32	− 32	27·32	0·0000	0·97341	0·0000
10	·92	·43	·32	+ 31	·37	10·2734	·97336	9·7339
25	·94	·44	·32	+ 23	·43	25·6845	·97331	24·3338
50	·91	·44	·33	+ 2	·57	51·3721	·97318	48·6649
75	·91	·44	·33	+ 2	·68	77·0628	·97308	72·9931
100	·91	·44	·33	+ 25	·80	102·7563	·97297	97·3187
150	·89	·45	·34		28·04	154·152	·97274	145·961

Stat. **7**. 17. April 1910. 49° 54′ N. 12° 10′ W. 1813 m.

0	10·6	35·46	27·23	+ 92	27·23	0·0000	0·97349	0·0000
10	·55	·46	·23	+ 62	·28	10·2726	·97344	9·7317
25	·50	·46	·24	+ 28	·35	25·6823	·97338	24·3358
50	·42	·45	·24	− 22	·48	51·3678	·97327	48·6689
75	·41	·44	·24	+ 9	·59	77·0562	·97316	72·9992
100	10·40	35·44	27·24	+ 51	27·70	102·7474	0·97306	97·3269
150	·35	·46	·27	+ 62	·97	154·133	·97281	145·973
200	·27	·48	·30	+ 15	28·22	205·544	·97257	194·608
300	·20	·48	·31	+ 13	·71	308·391	·97214	291·843
400	·10	·47	·32	+ 24	29·18	411·286	·97170	389·035
500	9·94	·46	·34	+ 38	·66	514·228	·97125	486·183
600	·66	·44	·37	+ 68	30·17	617·220	·97080	583·285
700	·25	·43	·43	+ 98	·69	720·263	·97032	680·341
800	8·80	·45	·52	+ 87	31·25	823·361	·96980	777·347
900	·40	·47	·60	+ 92	·80	926·513	·96930	874·302
1000	7·83	·46	·68	+ 56	32·35	1029·721	·96879	971·206
1200	6·38	·29	·75	+ 33	33·39	1236·295	·96786	1164·870
1400	4.85	·06	·77		34·39	1443·074	·96693	1358·349

Stat. **8**. 18. April 1910. 48° 53′ N. 11° 31′ W.

0	10·95	35·49	27·18	+ 93	27·18	0·0000	0·97354	0·0000
10	·90	·49	·19	+ 47	·24	10·2721	·97348	9·7351
25	·82	·48	·20	+ 31	·31	25·6813	·97342	24·3368
50	·78	·48	·20	+ 31	·44	51·3657	·97330	48·6708
75	·74	·48	·21	+ 31	·56	77·0533	·97319	73·0018
100	·70	·48	·22	− 2	·68	102·7438	·97308	97·3301
150	·67	·47	·22	+ 10	·92	154·134	·97285	145·978
200	·65	·47	·22	+ 8	28·15	205·536	·97264	194·616
300	·58	·46	·23	+ 14	·63	308·375	·97221	291·858
400	·52	·46	·24	+ 17	29·10	411·262	·97178	389·057
500	·44	·46	·25	+ 28	·57	514·196	·97134	486·213
600	·30	·46	·28	+ 76	30·07	617·178	·97089	583·325
700	·03	·49	·35	+123	·60	720·202	·97041	680·389
800	9·63	·55	·46	+140	31·18	823·302	·96987	777·403
900	·13	·61	·59	+ 96	·78	926·450	·96932	874·362
1000	8·65	·62	·68		32·34	1029·656	·96882	971·269

Stat. **9**. 18. April 1910. 47° 49′ N. 10° 52′ W.

0	11·0	35·54	27·21	+ 53	27·21	0·0000	0·97351	0·0000
10	10·93	·53	·22	+ 99	·27	10·2724	·97345	9·7348
25	·85	·53	·23	+ 30	·34	25·6820	·97339	24·3361
50	·77	·52	·24	+ 0	·48	51·3673	·97327	48·6692
75	·73	·51	·24	+ 24	·59	77·0558	·97316	72·9995
100	·70	·51	·24	− 2	·71	102·7471	·97306	97·3272
150	·67	·50	·24	− 6	·94	154·138	·97284	145·974
200	·65	·49	·24	+ 12	28·17	205·541	·97263	194·611
300	·60	·49	·24	+ 6	·64	308·382	·97221	291·852
400	·50	·47	·25	+ 6	29·11	411·270	·97177	389·051
500	·40	·45	·25	+ 23	·57	514·204	·97134	486·206
600	·25	·44	·27	+ 40	30·06	617·186	·97090	583·318
700	·05	·44	·31		·56	720·218	·97045	680·385

Numerical Value of Argument, a	a = m, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	a = D, Dynamic Metres: Density in situ σ_t, D	Pressure Decibars	a = p, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
800	9·75	35·48	27·39	+ 89	31·11	823·301	0·96994	777·404
900	·35	·52	·48	+107	·66	926·440	·96943	874·373
1000	8·85	·52	·57	+ 93	32·22	1029·634	·96892	971·290
Stat. 10 19—20. April 1910. 45° 26′ N. 9° 20′ W. 4700 m.								
0	12·3	35·56	26·98		26·98	0·0000	0·97373	0·0000
10	·20	·57	27.01	+ 276	27·06	10·2702	·97365	9·7369
25	11·75	·58	·10	+ 634	·21	25·6773	·97352	24·3406
50	·40	·59	·18	+ 300	·42	51·3602	·97332	48·6763
75	·28	·59	·20	+ 93	·55	77·0474	·97320	73·0078
100	·20	·58	·21	+ 31	·68	102·7378	·97308	97·3362
150	·10	·55	·20	— 7	·90	154·127	·97287	145·985
200	·05	·53	·20	— 10	28·13	205·528	·97266	194·623
300	10·93	·52	·21	+ 17	·60	308·365	·97223	291·868
400	·80	·53	·24	+ 35	29·10	411·250	·97178	389·068
500	·67	·54	·27	+ 35	·59	514·185	·97133	486·223
600	·56	·54	·29	+ 23	30·08	617·169	·97089	583·331
700	·45	·56	·33	+ 39	·58	720·202	·97043	680·400
800	·45	·69	·43	+ 102	31·14	823·288	·96990	777·416
900	·28	·82	·56	+ 135	·72	926·431	·96937	874·379
1000	9·90	·84	·64	+ 91	32·26	1029.630	·96887	971·291
1200	8·70	·71	·74	+ 65	33·32	1236·189	·96792	1164·969
1400	7·35	·51	·79	+ 47	34·33	1442·954	·96700	1358·461
1600	5·87	·28	·81	+ 39	35·31	1649·918	·96610	1551·771
1800	4·52	·10	·83	+ 40	36·32	1857·082	·96520	1744·900
2000	3·50	34·98	·84	+ 33	37·31	2064·445	·96432	1937·852
3000	2·44	·90	·88	+ 11·8	42·02	3104·11	·96011	2900·06
4000	·50	·90	·875	+ 1·0	46·55	4148·40	·95611	3858·17
Stat. 11. 21. April 1910. 44° 25′ N. 9° 18′ W.								
0	11·95	35·61	27·09		27·09	0·0006	0·97363	0·0000
10	·87	·61	·11	+ 157	·16	10·2713	·97356	9·7360
25	·77	·62	·13	+ 183	·24	25·6793	·97349	24·3388
50	·62	·62	·16	+ 117	·40	51·3623	·97334	48·6741
75	·50	·62	·18	+ 94	·53	77·0490	·97322	73·0060
100	·40	·61	·19	+ 47	·66	102·7390	·97310	97·3350
150	·22	·56	·19	— 7	·89	154·128	·97288	145·984
200	·08	·53	·19	+ 9	28·12	205·528	·97267	194·623
300	10·85	·52	·22	+ 38	·62	308·365	·97222	291·868
400	·68	·52	·26	+ 34	29·12	411·253	·97176	389·066
500	·58	·54	·29	+ 37	·61	514·190	·97130	486·242
600	·56	·56	·31	+ 22	30·10	617·176	·97087	583·350
700	·62	·60	·33	+ 22	·58	720·210	·97043	680·415
Stat. 12. 21. April 1910. 43° 11′ N. 9° 26′ W. 166 m.								
0	13·15	35·46	26·74		26·74	0·0000	0·97396	0·0000
10	12·18	·47	·94	+2020	·99	10·2787	·97372	9·7384
25	·18	·48	·94	+ 55	27·05	25·6840	·97366	24·3437
50	12·05	35·53	27·01	+ 260	27·25	51·3628	0·97348	48·6829
75	11·78	·59	·11	+ 398	·46	77·0467	·97329	73·0175
100	·69	·62	·15	+ 165	·62	102·7353	·97314	97·3478
150	·55	·60	·16	+ 25	·86	154·122	·97291	145·999
Stat. 13. 22. April 1910. 41° 32′ N. 9° 5′ W. 78 m.								
0	15·2	33·84	25·06		25·06	0·0000	0·97555	0·0000
10	14·32	34·66	·88	+8227	·93	10·2550	·97472	9·7514
25	13·25	35·31	26·60	+4835	26·71	25·6498	·97399	24·3666
50	12·27	·59	27·01	+1660	27·25	51·3243	·97348	48·7100
75	11·90	·62	·11	+ 384	·46	77·0083	·97329	73·0445
Stat. 16. 23. April 1910. 40° 15′ N. 9° 23′ W. 154 m.								
0	13·9	35·56	26·66		26·66	0·0000	0·97403	0·0000
10	·87	·54	·65	— 88	·70	10·2668	·97399	9·7401
25	·79	·53	·66	+ 64	·77	25·6679	·97393	24·3495
50	·02	·60	·87	+ 860	27·10	51·3414	·97361	48·6937
75	12·90	·67	·95	+ 317	·29	77·0214	·97344	73·0317
100	·76	·70	27·00	+ 209	·46	102·7058	·97329	97·3657
150	·30	·72	·11	+ 219	·81	154·088	·97297	146·022
Stat. 17. 23. April 1910. 38° 20′ N. 9° 43′ W. 1860 m.								
0	14·8	35·81	26·65		26·65	0·0000	0·97404	0·0000
10	·80	·81	·65	+ 3	·70	10·2667	·97399	9·7402
25	·77	·81	·66	+ 48	·77	25·6678	·97393	24·3495
50	13·94	·82	·85	+ 755	27·08	51·3411	·97364	48·6940
75	·87	·87	·91	+ 217	·26	77·0204	·97347	73·0328
100	·78	·89	·94	+ 142	·40	102·7036	·97334	97·3679
150	·48	·89	27·00	+ 130	·70	154·081	·97307	146·028
200	·02	·83	·05	+ 104	·97	205·473	·97282	194·675
300	12·07	·69	·13	+ 89	28·52	308·297	·97232	291·932
400	11·47	·63	·20	+ 75	29·05	411·175	·97182	389·139
500	·00	·65	·30	+ 109	·61	514·109	·97130	486·295
600	10·60	·77	·47	+ 171	30·26	617·102	·97072	583·396
700	·35	·93	·63	+ 173	·88	720·159	·97015	680·439
800	·31	36·10	·77	+ 141	31·48	823·277	·96959	777·425
900	·63	·28	·86	+ 78	32·02	926·452	·96909	874·359
1000	11·21	·44	·88	+ 8	·47	1029·676	·96867	971·247
1200	·46	·52	·89	+ 8	33·39	1236·263	·96785	1164·898
1400	10·24	·25	·90	+ 27	34·35	1443·038	·96698	1358·381
1600	7·37	35·68	·92	+ 64	35·37	1650·010	·96609	1551·687
Stat. 18 A. 29. April 1910. 35° 56′ N. 5° 43′ W. 400 m.								
0	17·0	36·12	26·39		26·39	0·0000	0·97429	0·0000
10	16·80	·14	·45	+ 635	·49	10·2644	·97419	9·7424
25	15·00	·30	·99	+3583	27·10	25·6664	·97362	24·3509
50	13·17	37·96	28·67	+ 6721	28·90	51·3665	·97192	48·6701
75	12·95	38·24	·93	+1057	29·28	77·0938	·97156	72·9635

Numerical Value of Argument a	a = m, Common Metres: Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	a = D, Dynamic Metres: Density in situ $\sigma_{t,D}$	Pressure Decibars	a = p, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
100	12·92	38·32	29·01	+ 276	29·47	102·8282	0·97138	97·2502
150	·91	·38	·05	+ 100	·74	154·309	·97113	145·813
200	·90	·39	·06	+ 23	·97	205·802	·97092	194·364
300	·87	·39	·06	+ 10	30·43	308·822	·97050	291·435
400	·89	·40	·07	+ 7	·89	411·878	·97008	388·463

Stat. **19 A**. 2. May 1910. 36° 5′ N. 4° 42′ W.

a	Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces Dynamic Metres
0	16·4	36·36	26·73	+ 472	26·73	0·0000	0·97396	0·0000
10	·21	·36	·76	+ 882	·80	10·2677	·97389	9·7393
25	15·63	·36	·89	+1149	27·00	25·6712	·97371	24·3463
50	14·70	·46	27·18	+ 417	·41	51·3514	·97333	48·6842
75	·58	·56	·28	+ 571	·63	77·0395	·97313	73·0149
100	·32	·67	·43	+2893	·89	102·7335	·97288	97·3400
150	13·05	38·19	28·87	+ 293	29·56	154·170	·97131	145·945
200	12·95	·35	29·02	+ 52	·93	205·657	·97095	194·501
300	·94	·41	·07	+ 15	30·44	308·676	·97050	291·573
400	·92	·42	·08	0	·90	411·744	·97007	388·601
500	·90	·41	·08	+ 8	31·36	514·857	·96965	485·587
600	·88	·41	·08	+ 8	·82	618·017	·96924	582·531
700	·86	·41	·08	— 2	32·27	721·221	·96882	679·433
800	·85	·40	·08	+ 6	·72	824·471	·96841	776·295
900	·84	·40	·08	+ 6	33·17	927·766	·96800	873·115
1000	·83	·40	·08		·62	1031·106	·96759	969·894

Stat. **20**. 5. May 1910. 35° 25′ N. 6° 25′ W. 141 m.

a	Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces Dynamic Metres
0	16·8	36·27	26·55	+ 94	26·55	0·0000	0·97414	0·0000
10	·73	·26	·56	+ 881	·60	10·2658	·97408	9·7411
25	·27	·29	·69	+ 973	·80	25·6663	·97390	24·3508
50	14·87	·19	·94	+ 151	27·17	51·3410	·97355	48·6939
75	·39	·10	·97	+ 123	·32	77·0222	·97342	73·0310
100	13·93	·01	27·00		·46	102·7070	·97329	97·3649

Stat. **22**. 5. May 1910. 35° 42′ N. 6° 51′ W. 835 m.

a	Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces Dynamic Metres
0	18·6	36·37	26·19	+ 131	26·19	0·0000	0·97448	0·0000
10	·52	·36	·20	+1762	·25	10·2622	·97443	9·7445
25	17·40	·34	·46	+1095	·57	25·6584	·97412	24·3586
50	16·20	·32	·73	+ 471	·96	51·3276	·97375	48·7069
75	15·63	·30	·85	+ 273	27·19	77·0046	·97353	73·0479
100	·20	·26	·92	+ 56	·38	102·6867	·97336	97·3840
150	14·32	·04	·94	+ 92	·63	154·062	·97313	146·046
200	13·58	35·89	·98	+ 157	·90	205·450	·97288	194·696
300	12·40	·77	27·13	+ 86	28·51	308·271	·97232	291·956
400	11·60	·67	·20	+ 62	29·05	411·150	·97183	389·164
500	·02	·60	·26	+ 83	·58	514·081	·97134	486·322
600	10·72	·63	·34	+ 79	30·13	617·067	·97084	583·431
700	·64	·71	·41	+ 70	·66	720·107	·97035	680·490
800	·57	·78	·48		31·19	823·200	·96987	777·501

Stat. **23**. 5. May 1910. 35° 32′ N. 7° 7′ W. 1215 m.

a	Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces Dynamic Metres
0	17·9	36·36	26·36	+ 251	26·36	0·0000	0·97432	0·0000
10	·80	·36	·38	+ 960	·43	10·2639	·97426	9·7429
25	·15	·34	·52	+1111	·63	25·6619	·97406	24·3552
50	15·75	·27	·80	+ 338	27·03	51·3328	·97369	48·7020
75	·35	·26	·88	+ 168	·22	77·0111	·97351	73·0419
100	·10	·24	·92	+ 49	·38	102·6936	·97336	97·3777
150	14·55	·11	·94	+ 102	·63	154·069	·97313	146·040
200	13·83	35·97	·99	+ 123	·91	205·458	·97288	194·690
300	12·49	·76	27·10	+ 50	28·48	308·277	·97235	291·951
400	11·60	·59	·14	+ 88	29·00	411·152	·97189	389·163
500	·00	·55	·22	+ 91	·53	514·078	·97138	486·326
600	10·74	·60	·31	+ 95	30·10	617·060	·97087	583·438
700	·62	·69	·40	+ 99	·65	720·098	·97036	680·500
800	·40	·76	·49	+ 89	31·20	823·191	·96986	777·511
900	·11	·80	·58	+ 77	·75	926·338	·96934	874·470
1000	·00	·87	·65	+ 49	32·27	1029·539	·96886	971·380
1200	·50	36·12	·76		33·29	1236·096	·96794	1165·060

Stat. **25 B**. 8. May 1910. 35° 46′ N. 8° 16′ W.

a	Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces Dynamic Metres
0	17·8	36·41	26·42	— 148	26·42	0·0000	0·97426	0·0000
10	·80	·39	·40	— 33	·45	10·2644	·97423	9·7425
25	·73	·36	·40	+1502	·51	25·6616	·97418	24·3555
50	15·76	·24	·77	+ 336	·98	51·3303	·97373	48·7044
75	·33	·22	·85	+ 208	27·19	77·0075	·97353	73·0451
100	·00	·19	·91	+ 191	·37	102·6896	·97337	97·3814
150	14·05	·04	·99	+ 88	·68	154·066	·97308	146·043
200	13·42	35·92	27·04	+ 57	·96	205·457	·97283	194·690
300	12·50	·74	·08	+ 50	28·46	308·278	·97237	291·950
400	11·73	·60	·12	+ 55	·97	411·150	·97191	389·164
500	·31	·56	·17	+ 103	29·49	514·074	·97144	486·331
600	·23	·67	·27	+ 143	30·06	617·051	·97092	583·449
700	·41	·90	·42	+ 107	·66	720·087	·97036	680·512
800	·31	36·01	·52	+ 84	31·22	823·181	·96984	777·522
900	10·83	35·99	·59	+ 71	·75	926·330	·96934	874·481
1000	·64	36·03	·66	+ 66	32·28	1029·532	·96886	971·390
1200	11·07	·31	·80	+ 76	33·31	1236·091	·96791	1165·067
1400	8·50	35·84	·87	+ 36	34·37	1442·860	·96697	1358·554
1600	6·68	·50	·87	+ 26	35·34	1649·831	·96608	1551·859
1800	5·43	·29	·87	+ 23	36·31	1856·997	·96521	1744·988
2000	4·50	·15	·87		37·29	2064·357	·96435	1937·943

Stat. **26**. 8. May 1910. 36° 53′ N. 6° 48′ W. 50 m

a	Temp. °C.	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces Dynamic Metres
0	16·8	35·91	26·28	— 366	26·28	0·0000	0·97439	0·0000
10	·73	·84	·24	+3793	·28	10·2628	·97438	9·7439
25	14·55	·93	·80	+ 888	·91	25·6618	·97380	24·3552
50	13·33	·88	27·02		27·25	51·3389	·97348	48·6960

Stat. 27. 9. May 1910. 36° 31′ N. 7° 1′ W.

Numerical Value of Argument *a* (*a* *m*, Common Metres)	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ* σ_t, D (*a* *D*, Dynamic Metres)	Pressure Decibars	Specific Volume in m.³ ton (*a* *p*, Pressure (Decibars))	Depth of Isobaric Surfaces Dynamic Metres
0	17·45	36·39	26·49	+ 22	26·49	0·0000	0·97419	0·0000
10	·38	·37	·49	+ 180	·54	10·2651	·97415	9·7417
25	·24	·36	·52	+ 763	·63	25·6639	·97406	24·3532
50	16·25	·30	·71	+ 515	·94	51·3336	·97377	48·7009
75	15·60	·27	·83	+ 199	27·17	77·0101	·97355	73·0424
100	·25	·23	·88	+ 109	·34	102·6916	·97340	97·3792
150	14·50	·08	·93	+ 100	·62	154·066	·97314	146·043
200	13·75	35·93	·97	+ 93	·89	205·454	·97290	194·693
300	12·70	·76	27·06	+ 103	28·44	308·270	·97239	291·957
400	11·63	·61	15·		29·00	411·143	·97188	389·170

Stat. 28. 9. May 1910. 36° 0′ N. 7° 19′ W.

Depth	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ*	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	17·5	36·35	26·45	+ 248	26·45	0·0000	0·97423	0·0000
10	·40	·35	·47	+ 324	·52	10·2649	·97417	9·7420
25	·17	·34	·52	+ 336	·63	25·6635	·97406	24·3536
50	16·73	·31	·60	+ 694	·83	51·3318	·97388	48·7027
75	15·80	·25	·77	+ 321	27·11	77·0062	·97361	73·0463
100	·25	·19	·85	+ 108	·31	102·6865	·97343	97·3843
150	14·78	·12	·90	+ 100	·59	154·059	·97317	146·049
200	·25	·03	·95	+ 136	·87	205·446	·97291	194·701
300	12·87	35·82	27·07	+ 68	28·45	308·262	·97238	291·966
400	11·83	·63	·13	+ 51	·98	411·134	·97190	389·179
500	·15	·52	·17	+ 80	29·48	514·057	·97143	486·345
600	10·83	·54	·26	+ 105	30·04	617·031	·97092	583·462
700	·58	·61	·35	+ 196	·60	720·066	·97041	680·529
800	·85	·93	·55		31·25	823·159	·96980	777·539

Stat. 29. 9—10. May 1910. 35° 10′ N. 7° 55′ W.

Depth	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ*	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	17·8	36·36	26·38	− 292	26·38	0·0000	0·97430	0·0000
10	·92	·36	·35	− 96	·39	10·2639	·97428	9·7429
25	·95	·35	·33	+1723	·44	25·6601	·97424	24·3567
50	16·00	·30	·76	+ 312	·99	51·3281	·97372	48·7062
75	15·50	·25	·84	+ 170	27·18	77·0053	·97354	73·0470
100	·08	·18	·88	+ 151	·34	102·6869	·97340	97·3837
150	14·12	·00	·95	+ 104	·64	154·062	·97312	146·047
200	13·38	35·86	27·00	+ 68	·92	205·451	·97286	194·696
300	12·40	·68	·06	+ 108	28·44	308·269	·97239	291·958
400	11·60	·61	·16	+ 85	29·01	411·142	·97187	389·171
500	·30	·64	·24	+ 103	·55	514·070	·97136	486·332
600	·10	·72	·34	+ 123	30·12	617·054	·97085	583·442
700	10·80	·80	·45	+ 91	·69	720·095	·97033	680·501
800	·70	·89	·54	+ 82	31·24	823·191	·96981	777·507
900	·74	·99	·61	+ 78	·76	926·341	·96932	874·464
1000	·80	36·08	·67		32·27	1029·543	·96885	971·372

Stat. 30. 10. May 1910. 34° 38′ N. 8° 22′ W.

Depth	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ*	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	17·4	36·39	26·50	− 197	26·50	0·0000	0·97418	0·0000
10	·42	·37	·48	− 70	·52	10·2651	·97415	9·7417
25	·34	·33	·46	+1117	·57	25·6633	·97412	24·3536
50	16·01	·28	·75	+ 139	·98	51·3328	·97373	48·7017
75	15·93	·30	·78	+ 93	27·13	77·0092	·97360	73·0433
100	·80	·29	·80	+ 178	·26	102·6891	·97348	97·3818
150	14·60	·05	·88	+ 141	·57	154·060	·97319	146·048
200	13·72	35·89	·95	+ 125	·87	205·446	·97291	194·701
300	12·78	·79	27·07	+ 111	28·45	308·262	·97238	291·965
400	11·95	·71	·17	+ 70	29·02	411·136	·97186	389·177
500	·34	·64	·23	+ 96	·54	514·064	·97137	486·339
600	·02	·68	·32	+ 99	30·10	617·047	·97087	583·450
700	·35	·89	·42	+ 133	·65	720·085	·97036	680·511
800	10·85	·93	·54	+ 75	31·24	823·180	·96981	777·519
900	·69	·96	·61	+ 92	·77	926·330	·96932	874·476
1000	·61	36·08	·70		32·31	1029·534	·96882	971·383

Stat. 31. 10. May 1910. 33° 47′ N. 8° 27′ W. 184 m.

Depth	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ*	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	17·7	36·33	26·38	− 260	26·38	0·0000	0·97430	0·0000
10	·90	·36	·35	+ 933	·39	10·2639	·97428	9·7429
25	·30	·35	·49	+ 840	·60	25·6613	·97409	24·3556
50	16·03	·23	·70	+ 506	·93	51·3305	·97378	48·7039
75	15·28	·17	·83	+ 430	27·17	77·0069	·97356	73·0455
100	14·63	·12	·93	+ 171	·39	102·6890	·97335	97·3818
150	13·75	35·98	27·01		·70	154·066	·97307	146·042

Stat. 32. 10. May 1910. 33° 27′ N. 8° 32′ W. 105 m.

Depth	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ*	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	17·9	36·21	26·24	+ 99	26·24	0·0000	0·97443	0·0000
10	·80	·19	·25	+ 694	·29	10·2627	·97438	9·7440
25	·25	·15	·35	+ 2034	·16	25·6583	·97422	24·3585
50	14·83	·08	·86	+ 653	27·09	51·3278	·97363	48·7065
75	13·65	[35·96	27·02]	+ 169	·37	77·0086	·97337	73·0440
100	·60	[36·00	·06]		·52	102·6948	·97323	97·3765

Stat. 33. 11. May 1910. 31° 17′ N. 10° 6′ W. 100 m.

Depth	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density *in situ*	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	16·3	36·06	26·51	+ 124	26·51	0·0000	0·97417	0·0000
10	·38	·10	·52	+ 284	·56	10·2654	·97412	9·7414
25	·43	·17	·56	+ 494	·67	25·6646	·97402	24·3524
50	·07	·22	·69	+ 574	·92	51·3346	·97379	48·7000
75	15·35	·19	·83	+ 390	27·18	77·0109	·97356	73·0417
100	14·75	·14	·92		·38	102·6929	·97336	97·3782

Column groups: a = m, Common Metres (Temp., Salinity, Density, Stability); a = D, Dynamic Metres (Density in situ, Pressure); a = p, Pressure (Decibars) (Specific Volume, Depth of Isobaric Surfaces).

Stat. 34. 13. May 1910. 28° 52′ N. 14° 16′ W. 2170 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	18·1	36·59	26·48	−1278	26·48	0·0000	0·97420	0·0000
10	·55	·57	·35	− 641	·39	10·2644	·97428	9·7424
25	·90	·56	·25	+1180	·36	25·6600	·97432	24·3569
50	17·82	·59	·55	+ 406	·78	51·3243	·97392	48·7099
75	·35	·57	·65	+ 155	·99	76·9965	·97372	73·0554
100	·10	·54	·69	+ 51	27·14	102·6732	·97358	97·3967
150	16·75	·46	·71	+ 155	·39	154·037	·97335	146·070
200	15·98	·32	·78	+ 218	·69	205·414	·97309	194·731
300	13·63	35·91	·98	+ 113	28·36	308·216	·97247	292·008
400	12·45	·73	27·09	+ 118	·93	411·081	·97194	389·229
500	11·37	·60	·19	+ 109	29·50	514·003	·97141	486·396
600	10·70	·57	·29	+ 102	30·08	616·982	·97089	583·511
700	·05	·54	·38	+ 95	·63	720·018	·97038	680·574
800	9·34	·49	·46	+ 83	31·19	823·109	·96987	777·586
900	8·63	·43	·53	+ 93	·73	926·255	·96937	874·548
1000	7·75	·35	·61		32·29	1029·456	·96885	971·459

Stat. 35. 18. May 1910. 27° 27′ N. 14° 52′ W. 2603 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	18·6	36·37	26·19	− 175	26·19	0·0000	0·97448	0·0000
10	·55	·33	·17	+ 207	·22	10·2620	·97446	9·7447
25	·43	·33	·20	+ 920	·31	25·6560	·97437	24·3609
50	17·82	·43	·43	+ 734	·66	51·3182	·97404	48·7159
75	·20	·47	·61	+ 270	·95	76·9884	·97376	73·0634
100	16·67	·39	·68	+ 164	27·14	102·6645	·97359	97·4052
150	15·78	·22	·75	+ 144	·44	154·029	·97331	146·078
200	14·90	·05	·82		·74	205·409	·97304	194·736

Stat. 38. 20. May 1910. 26° 3′ N. 14° 36′ W. 77 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	19·2	36·15	25·87	+3053	25·87	0·0000	0·97478	0·0000
10	18·00	·15	26·17	+2577	26·22	10·2605	·97445	9·7462
25	16·50	·18	·55	+ 794	·66	25·6571	·97404	24·3598
50	15·82	·23	·75	+ 47	·98	51·3277	·97383	48·7080
75	·74	·22	·76		27·10	77·0038	·97371	73·0522

Stat. 39 A. 20. May 1910. 26° 3′ N. 15° 0′ W. 214 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	19·2	36·48	26·12	+ 804	26·12	0·0000	0·97454	0·0000
10	18·80	·45	·20	+ 733	·25	10·2619	·97443	9·7448
25	·40	·46	·31	+ 376	·42	25·6569	·97426	24·3600
50	·00	·45	·40	+ 123	·63	51·3200	·97407	48·7140
75	17·85	·44	·43	+ 133	·77	76·9875	·97393	73·0640
100	·72	·44	·46	+ 260	·91	102·6586	·97380	97·4106
150	·20	·44	·59	+ 267	27·28	154·013	·97347	146·092
200	16·10	·36	·72		·63	205·386	·97314	194·757

Stat. 40. 22—23. May 1910. 28° 15′ N. 13° 29′ W. 1197 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	18·4	36·44	26·29	− 401	26·29	0·0000	0·97438	0·0000
10	·50	·42	·25	+ 5	·29	10·2629	·97438	9·7438
25	·50	·42	·25	+ 931	·36	25·6578	·97432	24·3590
50	17·60	·43	·48	+ 427	·71	51·3212	·97399	48·7128
75	·07	·40	·59	+ 301	·93	76·9917	·97378	73·0599
100	16·73	·39	·66	+ 326	27·11	102·6673	·97361	97·4022
150	·05	·39	·82	+ 276	·51	154·033	·97327	146·074
200	15·43	·38	·95	+ 90	·87	205·417	·97292	194·729
300	13·88	·04	27·03	+ 49	28·41	308·231	·97242	291·995
400	12·50	35·72	·07	+ 115	·91	411·098	·97196	389·214
500	11·17	·52	·17	+ 133	29·48	514·018	·97143	486·384
600	9·95	·39	·28	+ 105	30·08	616·996	·97090	583·500
700	8·91	·28	·37	+ 75	·64	720·032	·97038	680·563
800	·12	·20	·43	+ 117	31·18	823·123	·96986	777·575
900	7·52	·22	·54	+ 67	·76	926·270	·96933	874·534
1000	·12	·22	·59		32·28	1029·473	·96885	971·443

Stat. 44. 28. May 1910. 28° 37′ N. 19° 8′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	19·2	36·87	26·41	− 253	26·41	0·0000	0·97427	0·0000
10	·27	·86	·39	− 287	·43	10·2642	·97425	9·7426
25	·35	·83	·34	+ 19	·45	25·6609	·97424	24·3562
50	·22	·79	·35	+ 736	·58	51·3238	·97411	48·7105
75	18·60	·82	·53	+ 238	·87	76·9919	·97384	73·0598
100	·19	·76	·59	+ 93	27·04	102·6658	·97368	97·4037
150	17·40	·56	·63	+ 143	·32	154·025	·97343	146·081
200	16·58	·39	·70	+ 226	·61	205·398	·97316	194·746
300	14·46	·04	·91	+ 91	28·28	308·193	·97253	292·030
400	13·10	35·77	·99	+ 130	·84	411·049	·97203	389·258
500	12·00	·64	27·10	+ 115	29·42	513·962	·97150	486·434
600	11·00	·53	·21	+ 119	·99	616·933	·97097	583·557
700	10·07	·45	·31	+ 113	30·56	719·961	·97045	680·628
800	9·17	·38	·41	+ 126	31·14	823·046	·96991	777·645
900	8·34	·35	·51	+ 98	·72	926·189	·96938	874·609
1000	7·96	·39	·60	+ 76	32·27	1029·389	·96887	971·522
1200	·27	·43	·73	+ 40	33·34	1235·951	·96790	1165·198
1400	6·45	·35	·79	+ 38	34·36	1442·721	·96697	1358·684
1600	5·58	·26	·83	+ 32	35·35	1649·693	·96607	1551·988
1800	4·82	·18	·86	+ 39	36·33	1856·862	·96519	1745·114
2000	·00	·11	·90		37·34	2064·230	·96430	1938·063

Stat. 46. 29. May 1910. 28° 56′ N. 21° 45′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	Density in situ σ_t, D	Pressure Decibars	Specific Volume in m³/ton	Depth of Isobaric Surfaces Dynamic Metres
0	19·7	37·00	26·38	− 309	26·38	0·0000	0·97430	0·0000
10	·79	36·99	·35	− 227	·39	10·2639	·97428	9·7429
25	·72	·92	·32	+ 394	·43	25·6601	·97425	24·3569
50	·00	·80	·41		·64	51·3235	·97406	48·7107

Numerical Value of Argument a	a = m, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	a = D, Dynamic Metres: Density in situ $\sigma_{t,D}$	Pressure Decibars	a = p, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
75	18·10	36·69	26·56	+ 587	26·90	76·9927	0·97381	73·0590
100	17·80	·65	·60	+ 182	27·05	102·6671	·97367	97·4025
150	·63	·62	·62	+ 43	·30	154·026	·97344	146·080
200	·20	·55	·67	+ 110	·57	205·398	·97319	194·746
300	14·65	·01	·84	+ 191	28·20	308·187	·97260	292·035
400	13·05	35·77	27·00	+ 165	·84	411·039	·97203	389·267
500	12·03	·63	·09	+ 105	29·40	513·951	·97151	486·443
600	11·13	·52	·18	+ 96	·96	616·920	·97100	583·569
700	10·31	·48	·29	+ 129	30·54	719·945	·97047	680·642
800	9·58	·50	·43	+ 154	31·15	823·030	·96989	777·660
900	8·90	·52	·56	+ 141	·75	926·175	·96935	874·622
1000	·16	·46	·63	+ 86	32·30	1029·378	·96884	971·531
1200	6·84	·37	·75	+ 79	33·38	1235·946	·96786	1165·201
1400	5·98	·29	·81	+ 41	34·39	1442·723	·96694	1358·680
1600	·27	·22	·84	+ 32	35·37	1649·700	·96606	1551·980
1800	4·58	·14	·86	+ 25	36·34	1856·872	·96518	1745·104
2000	3·88	·06	·87	+ 25	37·32	2064·239	·96432	1938·053

Stat. 49 C. 2. June 1910. 29° 2′ N. 25° 30′ W.

0	19·65	36·73	26·19		26·19	0·0000	0·97448	0·0009
10	·60	·72	·20	+ 61	·24	10·2622	·97443	9·7445
25	·55	·72	·21	+ 93	·32	25·6564	·97436	24·3604
50	·30	·73	·28	+ 297	·51	51·3168	·97418	48·7171
75	18·60	·75	·48	+ 758	·82	76·9835	·97388	73·0678
100	·24	·75	·57	+ 370	27·02	102·6566	·97370	97·4125
150	17·92	·69	·60	+ 74	·28	154·014	·97347	146·092
200	·43	·56	·62	+ 50	·52	205·384	·97324	194·759
300	15·61	·18	·76	+ 149	28·12	308·167	·97268	292·055
400	13 88	35·91	·93	+ 186	·76	411·011	·97209	389·294
500	12·25	·69	27·09	+ 178	29·39	513·919	·97152	486·474
600	10·99	·54	·22	+ 137	30·00	616·889	·97096	583·598
700	·35	·48	·28	+ 79	·53	719·916	·97048	680·669
800	9·64	·45	·38	+ 111	31·10	822·997	·96994	777·690
900	8·78	·44	·52	+ 150	·72	926·139	·96938	874·656
1000	·16	·47	·64	+ 134	32·30	1029·340	·96884	971·567
1200	7·18	·47	·78	+ 86	33·39	1235·910	·96784	1165·235
1400	6·21	·35	·82	+ 36	34·39	1442·689	·96693	1358·712
1600	5·35	·24	·84	+ 28	35·36	1649·665	·96606	1552·010
1800	4·64	·16	·86	+ 27	36·34	1856·836	·96518	1745·134

Stat. 50. 4. June 1910. 30° 8′ N. 31° 19′ W.

0	20·4	36·81	26·05		26·05	0·0000	0·97461	0·0000
10	·40	·79	·04	— 147	·09	10·2607	·97458	9·7459
25	·37	·78	·04	+ 8	·15	25·6525	·87452	24·3641
50	19·98	·87	·21	+ 697	·44	51·3099	·97425	48·7237
75	18·56	·61	·38	+ 696	·72	76·9744	·97398	73·0765
100	18·16	36·55	26·44	226	26·89	102·6806	0·97382	97·4240
150	17·84	·53	·50	135	27·18	154·033	·97355	146·108
200	·50	·50	·56	+ 128	·47	205·390	·97330	194·779
300	15·80	·14	·69	+ 139	28·06	308·175	·97275	292·081
400	14·66	·00	·83	158	·65	411·011	·97220	389·329
500	13·00	35·75	·99	174	29·28	513·908	·97162	486·519
600	11·77	·59	27·11	134	·88	616·866	·97107	583·654
700	10·82	·51	·22	+ 130	30·46	719·884	·97054	680·734
800	9·93	·46	·34	+ 133	31·05	822·960	·96999	777·760
900	·20	·44	·45	122	·64	926·095	·96945	874·732
1000	8·64	·48	·57	+ 134	32·23	1029·288	·96891	971·650
1200	7·57	·46	·72	+ 88	33·33	1235·844	·96791	1165·331
1400	6·40	·33	·78	+ 51	34·35	1412·612	·96698	1358·819
1600	5·34	·20	·81	+ 38	35·34	1649·581	·96609	1552·125
1800	4·58	·11	·83	+ 26	36·32	1856·748	·96521	1745·254
2000	·00	·05	·85	+ 23	37·30	2064·110	·96434	1938·208

Stat. 51. 6. June 1910. 31° 20′ N. 34° 56′ W. 3886 m.

0	20·6	36·61	25·85		25·85	0·0000	0·97480	0·0000
10	·57	·60	·85	+ 11	·90	10·2587	·97476	9·7478
25	·49	·58	·85	+ 51	·96	25·6477	·97470	24·3687
50	19·38	·57	26·14	+ 1156	26·37	51·3018	·97431	48·7313
75	18·50	·57	·36	+ 913	·70	76·9652	·97400	73·0852
100	·17	·56	·44	+ 309	·89	102·6352	·97382	97·4329
150	17·60	·45	·50	+ 122	27·18	153·987	·97355	146·117
200	·04	·33	·54	95	·45	205·353	·97331	194·789
300	15·90	·14	·66	+ 132	28·03	308·127	·97277	292·093
400	14·70	35·94	·78	+ 127	·60	410·959	·97225	389·344
500	13·38	·74	·91	+ 141	29·20	513·849	·97168	486·540
600	11·99	·59	27·07	+ 177	·81	616·801	·97110	583·679
700	10·78	·48	·21	+ 159	30·45	719·816	·97055	680·761
800	9·66	·41	·35	+ 160	31·07	822·893	·96997	777·787
900	8·56	·35	·48	+ 155	·68	926·031	·96942	874·756
1000	7·68	·31	·58	+ 123	32·26	1029·228	·96888	971·671
1200	6·59	·26	·70	+ 73	33·33	1235·788	·96791	1165·350
1400	5·85	·22	·77	+ 46	34·35	1442·557	·96697	1358·837
1600	·24	·19	·82	+ 38	35·35	1649·528	·96608	1552·142
1800	4·67	·14	·85	27	36·34	1856·697	·96520	1745·269
2000	·10	·09	·87	27	37·32	2064·063	·96433	1938·222

Stat. 53. 9. June 1910. 35° 7′ N. 32° 30′ W. 2865 m.

0	19·5	36·33	25·92		25·92	0·0000	0·97473	0·0000
10	·41	·27	·90	217	·94	10·2593	·97471	9·7472
25	·25	·22	·91	28	26·02	25·6491	·97464	24·3673
50	17·85	·25	26·28	+ 1513	·51	51·3057	·97418	48·7275
75	·00	·24	·48	+ 807	·82	76·9724	·97389	73·0782

Numerical Value of Argument a	$a = m$, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	$a = D$, Dynamic Metres: Density *in situ* σ_t, D	Pressure Decibars	$a = p$, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
100	16·63	36·20	26·54	+237	26·99	102·6451	0·97373	97·4233
150	·00	·14	·64	+209	27·33	154·003	·97312	146·102
200	15·30	·05	·73	+191	·65	205·382	·97312	194·765
300	13·70	35·79	·88	+159	28·26	308·177	·97256	292·049
400	12·73	·67	·98	+115	·82	411·032	·97204	389·279
500	11·65	·54	27·09	+121	29·40	513·943	·97151	486·456
600	10·43	·43	·23	+154	30·02	616·914	·97094	583·578
700	9·65	·37	·32	+101	·58	719·944	·97043	680·647
800	·00	·36	·42	+112	31·15	823·031	·96990	777·663
900	8·10	·38	·58	+175	·79	926·178	·96931	874·623
1000	7·50	·39	·67	+111	32·35	1029·386	·96880	971·528
1200	6·85	·36	·74	+44	33·37	1235·958	·96787	1165·194
1400	5·90	·24	·78	+33	34·36	1442·732	·96698	1358·679
1600	4·50	·08	·82	+49	35·38	1649·707	·96604	1551·980

Stat. 57. 11. June 1910. Ca. 37° 7′ N. 29° 41′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* σ_t, D	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	18·85	36·25	26·03		26·03	0·0000	0·97463	0·0000
10	·75	·24	·05	+184	·09	10·2606	·97457	9·7460
25	·10	·18	·17	+791	·28	25·6534	·97440	24·3632
50	16·25	·13	·57	+1642	·80	51·3170	·97391	48·7169
75	15·63	·10	·69	+487	27·03	76·9900	·97369	73·0618
100	·35	·08	·74	+199	·20	102·6679	·97354	97·4020
150	·05	·05	·79	+93	·48	154·035	·97328	146·072
200	14·70	·00	·83	+84	·75	205·416	·97303	194·730
300	13·77	35·86	·92	+100	28·30	308·218	·97252	292·007
400	12·77	·72	27·01	+108	·85	411·076	·97201	389·233
500	11·83	·59	·10	+94	29·41	513·989	·97150	486·409
600	·08	·50	·17	+81	·95	616·958	·97101	583·534
700	10·42	·45	·25	+91	30·50	719·980	·97051	680·609
800	9·82	·46	·36	+123	31·07	823·059	·96997	777·633
900	·23	·51	·50	+149	·69	926·197	·96941	874·601
1000	8·73	·53	·59	+108	32·24	1029·394	·96889	971·516
1200	7·65	·45	·70	+66	33·30	1235·949	·96793	1165·198
1400	6·28	·28	·75	+52	34·32	1442·712	·96701	1358·691
1600	5·03	·14	·80	+48	35·34	1649·679	·96609	1552·000
1800	4·03	·04	·83	+39	36·35	1856·849	·96518	1745·127

Stat. 58. 12. June 1910. 37° 37′ N. 29° 25′ W. 948 m.

a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* σ_t, D	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	19·2	36·18	25·89		25·89	0·0000	0·97476	0·0000
10	·16	·18	·90	+109	·95	10·2592	·97471	9·7473
25	18·95	·18	·95	+364	26·06	25·6493	·97461	24·3671
50	17·55	·18	26·30	+1410	·53	51·3067	·97416	48·7266
75	16·40	·17	·57	+1082	·91	76·9749	·97381	73·0761
100	15·89	·15	·67	+418	27·13	102·6504	·97360	97·4187
150	·20	·07	·77	+198	·46	154·015	·97330	146·091
200	14·65	35·99	26·83	+128	27·75	205·396	·97303	194·749
300	13·72	·84	·91	+92	28·29	308·198	·97253	292·027
400	12·82	·72	27·01	+101	·84	411·054	·97201	389·254
500	·02	·64	·10	+105	29·40	513·967	·97150	486·429
600	11·20	·56	·19	+104	·97	616·936	·97099	583·553
700	10·40	·49	·28	+103	30·53	719·961	·97048	680·626

Stat. 59. 17. June 1910. 38° 30′ N. 28° 37′ W. 225 m.

a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* σ_t, D	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	18·9	36·26	26·03		26·03	0·0000	0·97463	0·0000
10	·30	·22	·15	+1229	·20	10·2611	·97447	9·7455
25	17·60	·19	·30	+1009	·41	25·6557	·97427	24·3611
50	16·98	·17	·43	+546	·66	51·3192	·97404	48·7149
75	·18	·13	·59	+643	·93	76·9892	·97379	73·0626
100	15·80	·09	·65	+234	27·11	102·6647	·97362	97·4052
150	·40	·04	·70	+111	·39	154·027	·97336	146·080
200	14·68	35·94	·78	+176	·70	205·405	·97308	194·740

Stat. 60. 20 June 1910. 37° 9′ N. 38° 5′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* σ_t, D	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	19·8	36·25	25·79		25·79	0·0000	0·97486	0·0000
10	·70	·23	·79	+136	·85	10·2582	·97482	9·7484
25	·55	·21	·82	+167	·93	25·6466	·97473	24·3700
50	·45	·20	·84	+79	26·07	51·2966	·97460	48·7365
75	16·25	·11	26·57	+2903	·91	76·9483	·97381	73·0915
100	·03	·11	·61	+210	27·07	102·6231	·97366	97·4348
150	15·83	·10	·65	+82	·34	153·984	·97341	146·111
200	·40	·04	·70	+110	·62	205·358	·97315	194·775
300	14·27	35·86	·81	+119	28·18	308·148	·97263	292·064
400	13·13	·70	·93	+126	·76	410·995	·97209	389·300
500	11·55	·46	27·05	+139	29·36	513·901	·97154	486·481
600	10·02	·30	·20	+172	·99	616·869	·97096	583·606
700	8·65	·19	·34	+161	30·61	719·900	·97040	680·674
800	7·50	·16	·49	+171	31·25	822·993	·96981	777·684
900	6·60	·16	·62	+144	·86	926·149	·96924	874·636
1000	·07	·15	·68	+76	32·40	1029·362	·96875	971·535
1200	5·10	·07	·74	+43	33·43	1235·945	·96782	1165·192
1400	4·40	·02	·78	+33	34·42	1442·730	·96692	1358·665
1600	3·98	·00	·81	+24	35·39	1649·711	·96603	1551·960
1800	·70	34·97	·82	+10	36·35	1856·885	·96518	1745·081
2000	·50	·95	·82	+9	37·29	2064·249	·96434	1938·032

Stat. 63. 22. June 1910. 36° 5′ N. 43° 58′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* σ_t, D	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	22·2	36·45	25·29		25·29	0·0000	0·97533	0·0000
10	21·50	·42	·45	+1738	·50	10·2540	·97524	9·7528
25	19·20	·34	26·01	+3709	26·12	25·6111	·97455	24·3762
50	18·16	·37	·30	+1157	·53	51·2992	·97416	48·7350
75	17·50	·37	·46	+657	·80	76·9659	·97391	73·0858

Numerical Value of Argument a	$a = m$, Common Metres				$a = D$, Dynamic Metres		$a = p$, Pressure (Decibars)	
	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
100	17·33	36·34	26·48	+ 79	26·93	102·6377	0·97378	97·4318
150	16·96	·30	·54	+ 124	27·23	153·992	·97352	146·114
200	·60	·25	·58	+ 101	·49	205·360	·97328	194·784
300	15·95	·14	·65	+ 75	28·02	308·136	·97278	292·087
400	14·70	35·89	·74	+ 100	·56	410·965	·97228	389·340
500	13·13	·64	·88	+ 154	29·17	513·851	·97171	486·539
600	11·20	·39	27·06	+ 205	·84	616.802	·97111	583·680
700	8·90	·13	·26	+ 228	30·53	719·821	·97048	680·759
800	7·30	·12	·49	+ 261	31·25	822·910	·96981	777·773
900	6·05	·16	·69	+ 226	·94	926·070	·96917	874·722
1000	5·65	·15	·74	+ 53	32·47	1029·290	·96868	971·614
1200	·03	·06	·74	+ 12	33·43	1235·880	·96782	1165·264
1400	4·42	34·99	·76	+ 19	34·39	1442·663	·96694	1358·740
1600	3·83	·95	·78	+ 29	35·36	1649·638	·96606	1552·039
1800	·57	·94	·80	+ 16	36·34	1856·808	·96519	1745·163
2000	·42	·94	·82	+ 12	37·29	2064·171	·96433	1938·115

Stat. **64.** 24. June 1910. 34° 48′ N. 47° 52′ W.

0	22·8	36·58	25·21		25·21	0·0000	0·97541	0·0000
10	·30	·58	·35	+1436	·40	10·2531	·97523	9·7532
25	21·63	·58	·53	+1265	·64	25·6359	·97500	24·3799
50	19·60	·50	26·03	+1963	26·26	51·2846	·97442	48·7476
75	18·22	·43	·33	+1210	·67	76·9462	·97403	73·1031
100	17·90	·39	·38	+ 202	·83	102·6150	·97388	97·4519
150	·54	·35	·44	+ 121	27·13	153·964	·97361	146·139
200	·34	·33	·47	+ 72	·38	205·317	·97338	194·814
300	16·85	·26	·53	+ 71	·89	308·081	·97290	292·128
400	15·75	·10	·67	+ 145	28·49	410·900	·97235	389·390
500	13·72	35·77	·86	+ 210	29·15	513·782	·97174	486·594
600	12·35	·54	·96	+ 118	·73	616·726	·97121	583·742
700	10·86	·37	27·11	+ 172	30·36	719·731	·97065	680·834
800	9·14	·23	·29	+ 215	31·03	822·800	·97002	777·868
900	7·42	·14	·48	+ 230	·69	925·936	·96939	874·838
1000	6·27	·08	·60	+ 137	32·31	1029·137	·96883	971·749
1200	5·10	·02	·70	+ 67	33·39	1235·707	·96786	1165·417
1400	4·42	34·99	·75	+ 40	34·38	1442·484	·96695	1358·898
1600	3·92	·96	·78	+ 26	35·36	1649·459	·96606	1552·198
1800	·71	·95	·80	+ 13	36·33	1856·628	·96520	1745·324
2000	·60	·95	·81	+ 10	37·28	2063·989	·96435	1938·279

Stat. **65.** 25 June 1910. 37° 12′ N. 48° 30′ W.

0	21·8	36·37	25·35		25·35	0·0000	0·97528	0·0000
10	·40	·37	·45	+1118	·50	10·2543	·97514	9·7521
25	20·75	·36	·62	+1142	·73	25·6385	·97492	24·3775
50	19·90	·34	·82	+ 855	26·05	51·2857	·97462	48·7467
75	17·42	·32	26·44	+2473	·78	76·9462	·97392	73·1034

100	17·12	36·30	26·50	+ 236	26·96	102·6180	0·97376	97·4491
150	16·84	·27	·54	+ 94	27·23	153·973	·97352	146·131
200	·62	·24	·57	+ 64	·48	205·341	·97329	194·801
300	·18	·17	·62	+ 56	·99	308·114	·97282	292·107
400	15·60	·07	·68	+ 64	28·50	410·939	·97234	389·364
500	14·63	35·89	·76	+ 88	29·04	513·816	·97184	486·573
600	13·08	·63	·88	+ 144	·66	616·752	·97129	583·730
700	11·34	·40	27·04	+ 186	30·28	719·749	·97072	680·830
800	9·63	·24	·22	+ 206	·95	822·811	·97009	777·870
900	7·87	·11	·40	+ 210	31·62	925·939	·96947	874·848
1000	6·45	·05	·55	+ 186	32·26	1029·133	·96888	971·765
1200	4·88	34·99	·70	+ 101	33·39	1235·698	·96786	1165·438
1400	·39	·97	·74	+ 32	34·38	1442·475	·96695	1358·919
1600	·13	·97	·77	+ 22	35·35	1649·448	·96608	1552·221
1800	3·88	·96	·79	+ 17	36·31	1856·624	·96522	1745·350
2000	·65	·95	·80	+ 16	37·26	2063·982	·96436	1938·308

Stat. **66.** 26 – 27. June 1910. 39° 30′ N. 49° 42′ W.

0	19·85	34·57	24·50		24·50	0·0000	0·97609	0·0000
10	·60	·90	·81	+3169	·85	10·2468	·97575	9·7592
25	18·50	35·27	25·37	+3754	25·48	25·6243	·97516	24·3910
50	12·80	34·82	26·31	+3774	26·54	51·2746	·97415	48·7573
75	10·70	·80	·69	+1545	27·04	76·9445	·97397	73·1086
100	9·95	·81	·83	+ 564	·31	102·6239	·97344	97·4512
150	·05	·84	27·00	+ 353	·71	153·999	·97306	146·114
200	8·55	·86	·10	+ 196	28·04	205·393	·97276	194·759
300	7·73	·88	·23	+ 146	·64	308·227	·97219	292·007
400	6·62	·90	·41	+ 184	29·30	411·125	·97158	389·195
500	5·72	·93	·55	+ 152	·92	514·086	·97101	486·324
600	·15	·94	·63	+ 87	30·49	617·107	·97049	583·399
700	4·75	·96	·70	+ 70	31·03	720·183	·97000	680·424
800	·52	·97	·73	+ 39	·55	823·312	·96953	777·400
900	·38	·98	·75	+ 28	32·03	926·491	·96908	874·331
1000	·27	·99	·77	+ 24	·52	1029·719	·96863	971·216
1200	·00	·98	·79	+ 16	33·50	1236·322	·96775	1164·853
1400	3·70	·94	·79	+ 6	34·45	1443·117	·96688	1358·316
1600	·60	·94	·80	+ 8	35·39	1650·101	·96603	1551·607
1800	·50	·94	·81	+ 9	36·35	1857·276	·96518	1744·728

Stat. **67** & **67 A**. 27. June 1910. 40° 15′ N. 50° 37′ W.

0	20·6	36·03	25·40		25·40	0·0000	0·97523	0·0000
10	·70	·08	·41	+ 115	·45	10·2543	·97518	9·7520
25	·78	·13	·43	+ 114	·54	25·6367	·97510	24·3791
50	·68	·30	·49	+ 631	·72	51·2775	·97493	48·7544
75	·40	·38	·72	+ 552	26·06	76·9247	·97460	73·1235
100	19·77	·39	·90	+ 706	·35	102·5799	·97433	97·4851

Numerical Value of Argument a	a m, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	a D, Dynamic Metres: Density in situ $\sigma_{t,D}$	Pressure Decibars	a p, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
150	17·42	36·19	26·34	− 898	27·03	153·914	0·97371	146·186
200	16·85	·15	·46	+ 220	·37	205·274	·97339	194·863
300	15·93	·08	·61	+ 171	·97	308·041	·97283	292·174
400	14·70	35·90	·75	+ 149	28·57	410·868	·97228	389·429
500	12·60	·61	·96	+ 233	29·26	513·760	·97163	486·624
600	9·85	·31	27·24	+ 309	30·03	616·725	·97093	583·752
700	7·55	·10	·44	+ 233	·73	719·763	·97038	680·817
800	6·00	·00	·57	+ 163	31·36	822·808	·96980	777·826
900	5·10	34·97	·66	− 107	·93	926·032	·96918	874·775
1000	4·52	·95	·71	+ 66	32·46	1029·252	·96869	971·668

Stat. **68**. 28. June 1910. 39° 20′ N. 50° 50′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	21·5	36·26	25·33		25·33	0·0000	0·97529	0·0000
10	·45	·26	·34	+ 144	·38	10·2536	·97524	9·7527
25	·35	·26	·37	+ 190	·48	25·6351	·97516	24·3807
50	20·70	·27	·56	+ 746	·79	51·2760	·97486	48·7559
75	19·55	·36	·93	+1507	26·27	76·9267	·97440	73·1217
100	18·58	·41	26·22	+1162	·67	102·5885	·97403	97·4770
150	·12	·41	·34	+ 237	27·02	153·931	·97371	146·170
200	17·83	·39	·39	+ 120	·30	205·289	·97346	194·849
300	·32	·32	·47	+ 78	·83	308·045	·97296	292·170
400	16·76	·25	·55	+ 88	28·36	410·855	·97248	389·441
500	15·63	·04	·65	+ 115	·92	513·719	·97196	486·663
600	13·15	35·62	·86	+ 239	29·62	616·647	·97132	583·826
700	10·92	·34	27·07	+ 244	30·31	719·644	·97069	680·926
800	8·75	·16	·30	+ 266	31·04	822·711	·97001	777·961
900	6·65	·04	·52	+ 256	·75	925·851	·96934	874·928
1000	5·30	34·96	·63	+ 142	32·36	1029·057	·96878	971·833
1200	4·50	·95	·71	+ 54	33·41	1235·635	·96784	1165·495
1400	·27	35·01	·79	+ 41	34·43	1412·419	·96690	1358·969

Stat. **69**. 29. June 1910. 41° 39′ N. 51° 4′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	17·15	35·40	25·80		25·80	0·0000	0·97485	0·0000
10	·10	·36	·78	− 182	·82	10·2581	·97482	9·7484
25	16·95	·36	·82	+ 244	·93	25·6463	·97473	24·3699
50	·33	36·03	26·48	+2647	26·71	51·3044	·97399	48·7288
75	15·55	35·92	·57	+ 390	·91	76·9747	·97381	73·0762
100	14·86	·78	·63	+ 195	27·09	102·6498	·97364	97·4192
150	13·50	·56	·74	+ 252	·44	154·013	·97332	146·093
200	12·59	·45	·84	+ 210	·76	205·393	·97301	194·751
300	11·05	·35	27·06	+ 229	28·45	308·204	·97238	292·021
400	8·55	·09	·28	+ 243	29·15	411·085	·97173	389·226
500	6·86	·02	·47	+ 213	·83	514·034	·97110	486·367
600	5·56	·00	·63	+ 173	30·48	617·050	·97050	583·447
700	4·55	34·92	·68	+ 75	31·01	720·125	·97003	680·473
800	·33	·91	·70	+ 23	·52	823·252	·96956	777·452

Numerical Value of Argument a	a m, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	a D, Dynamic Metres: Density in situ $\sigma_{t,D}$	Pressure Decibars	a p, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
900	4·18	34·92	27·72	+ 28	32·03	926·428	0·96910	874·385
1000	·02	·92	·74	+ 22	·50	1029·653	·96865	971·272
1200	3·67	·92	·78	+ 24	33·50	1236·253	·96775	1164·912
1400	·50	·92	·79	+ 13	34·46	1443·049	·96688	1358·375
1600	·42	·91	·79	+ 3	35·39	1650·034	·96603	1551·665
1800	·34	·90	·79	+ 3	36·33	1857·207	·96519	1744·787

Stat. **70.** 30 June 1910. 42° 59′ N. 51° 15′ W. 1100 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	11·95	32·64	24·78		24·78	0·0000	0·97582	0·0000
10	·75	·64	·83	+ 375	·88	10·2483	·97572	9·7577
25	9·10	·83	25·42	+4028	25·53	25·6264	·97511	24·3889
50	2·95	33·41	26·65	+4857	26·89	51·2818	·97382	48·7504
75	6·85	34·30	·91	+1038	27·26	76·9588	·97347	73·0914
100	7·97	·63	27·01	+ 387	·49	102·6432	·97326	97·4255
150	8·18	·85	·15	+ 281	·86	154·027	·97292	146·080
200	7·54	·89	·27	+ 259	28·21	205·429	·97260	194·718
300	6·25	·91	·47	+ 203	·89	308·284	·97196	291·946
400	5·20	·91	·60	+ 143	29·51	411·204	·97139	389·113
500	4·34	·90	·69	+ 102	30·08	514·183	·97087	486·226
600	·00	·90	·73	+ 42	·60	617·218	·97039	583·289
700	3·82	·90	·75	+ 23	31·09	720·302	·96994	680·305
800	·73	·90	·76	+ 12	·59	823·437	·96949	777·276
900	·70	·90	·76	+ 5	32·06	926·620	·96906	874·203
1000	·70	·90	·76	+ 1	·53	1029·849	·96862	971·087

Stat. **70 A.** 30. June 1910. Ca. 42° 55′ N. 51° 18′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	12·4	32·45	24·56		24·56	0·0000	0·97603	0·0000
10	11·70	·43	·68	+1164	·73	10·2464	·97587	9·7595
25	9·30	·58	25·20	+3516	25·31	25·6218	·97532	24·3934
50	4·25	33·48	26·57	+5521	26·81	51·2734	·97390	48·7585
75	6·30	34·12	·84	+1045	27·18	76·9484	·97353	73·1013
100	7·05	·43	·98	+ 562	·45	102·6314	·97330	97·4367
150	·65	·74	27·14	+ 311	·85	154·014	·97293	146·092
200	8·05	·91	·21	− 145	28·15	205·414	·97265	194·732

Stat. **71**. 30. June 1910. 43° 18′ N. 51° 17′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	12·2	32·61	24·71		24·71	0·0000	0·97589	0·0000
10	11·93	·71	·84	+1285	·89	10·2480	·79571	9·7580
25	10·40	·99	25·34	+3279	25·45	25·6256	·97518	24·3897
50	5·82	33·91	26·75	+5635	26·99	51·2811	·97372	48·7509
75	6·85	34·35	·95	+ 836	27·30	76·9598	·97343	73·0902
100	7·05	·46	27·00	+ 234	·47	102·6445	·97328	97·4240
150	·40	·57	·04	+ 72	·75	154·025	·97302	146·082

Numerical Value of Argument a	a = m, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	a = D, Dynamic Metres: Density in situ $\sigma_{t,D}$	Pressure Decibars	a = p, Pressure (Decibars): Specific Volume in m.³/ton	Depth of Isobaric Surfaces Dynamic Metres

Stat. 72. 1. July 1910. 44° 35′ N. 51° 15′ W. 72 m.

0	10·55	32·20	24·70	+ 207	24·70	0·0000	0·97590	0·0000
10	·43	·20	·72	+ 310	·77	10·2473	·97583	9·7587
25	·25	·22	·77	+5683	·88	25·6198	·97573	24·3953
50	2·03	·75	26·19	+ 160	26·43	51·2613	·97426	48·7701
75	·03	·80	·24		·60	76·9243	·97410	73·1244

Stat. 73. 1. July 1910. 45° 58′ N. 51° 25′ W. 70 m.

0	8·45	32·07	24·93	+1511	24·93	0·0000	0·97567	0·0000
10	·17	·21	25·08	+ 877	25·13	10·2503	·97548	9·7558
25	7·30	·22	·22	+4547	·33	25·6288	·97530	24·3866
50	0·35	·82	26·35		26·60	51·2780	·97410	48·7539

Stat. 74. 2. July 1910. 47° 25′ N. 52° 20′ W. 156 m.

0	7·2	32·25	25·25	+ 339	25·25	0·0000	0·97537	0·0000
10	6·95	·25	·28	+ 656	·33	10·2529	·97529	9·7533
25	·32	·27	·38	+3382	·49	25·6341	·97514	24·3815
50	0·35	·65	26·22	+ 788	26·47	51·2837	·97422	48·7485
75	—1·65	·80	·41	+ 366	·78	76·9493	·97393	73·1004
100	—1·44	·92	·50	+ 356	·99	102·6214	·97373	97·4461
150	—0·97	33·16	·69		27·42	153·982	·97331	146·122

Stat. 76. 9. July 1910. 47° 11′ N. 47° 6′ W.

0	5·9	32·89	25·91	+ 805	25·91	0·0000	0·97474	0·0000
10	·25	·92	26·02	+1637	26·07	10·2599	·97459	9·7467
25	4·10	33·07	·25	+3148	·37	25·6532	·97431	24·3634
50	—0·15	·65	27·03	+ 942	27·28	51·3238	·97345	48·7104
75	0·40	·98	·28	+ 522	·65	77·0105	·97311	73·0424
100	1·12	34·20	·41	+ 271	·90	102·7048	·97287	97·3672
150	2·15	·47	·55	+ 78	28·28	154·109	·97252	146·002
200	·87	·60	·60	+ 63	·56	205·530	·97225	194·621
300	3·35	·74	·67	+ 72	29·11	308·414	·97176	291·821
400	·35	·83	·74		·66	411·353	·97125	388·971

Stat. 77. 10. July 1910. 47° 18′ N. 44° 54′ W. 171 m.

0	8·45	33·23	25·84	+ 832	25·84	0·0000	0·97481	0·0000
10	7·73	·20	·92	+ 602	·97	10·2591	·97468	9·7475
25	·32	·24	26·01	+2342	26·12	25·6498	·97455	24·3666
50	2·55	·87	27·04	+ 794	27·28	51·3174	·97345	48·7166
75	·47	34·11	·24	+ 474	·60	77·0035	·97316	73·0491
100	·10	·22	·36	+ 286	·84	102·6966	·97293	97·3752
150	3·32	·54	·51		28·23	154·098	·97256	146·012

Stat. 79. 10 July 1910. 47° 16′ N. 44° 17′ W. 271 m.

0	9·2	33·30	25·77	+2537	25·77	0·0000	0·97488	0·0000
10	7·85	·36	26·02	+2593	26·07	10·2592	·97459	9·7471
25	6·40	·60	·42	+2925	·53	25·6537	·97416	24·3629
50	2·85	34·03	27·15	+ 702	27·39	51·3279	·97335	48·7067
75	·76	·24	·32	+ 351	·68	77·0163	·97308	73·0370
100	·67	·34	·41	+ 272	·89	102·7109	·97288	97·3615
150	·40	·48	·54	+ 105	28·27	154·115	·97253	145·997
200	·95	·61	·60		·56	205·536	·97225	194·616

Stat. 80. 11. July 1910. 47° 34′ N. 43° 11′ W.

0	11·8	34·24	26·06	+ 24	26·06	0·0000	0·97460	0·0000
10	·83	·25	·06	+ 261	·11	10·2609	·97455	9·7458
25	·83	·30	·10	+1385	·21	25·6533	·97446	24·3633
50	·60	·69	·43	+1878	·67	51·3144	·97403	48·7194
75	10·57	35·05	·91	+ 705	27·26	76·9885	·97347	73·0630
100	8·95	34·92	27·08	+ 185	·55	102·6737	·97321	97·3965
150	7·30	·71	·17	+ 187	·88	154·059	·97290	146·049
200	·20	·81	·26	+ 296	28·20	205·461	·97260	194·686
300	4·90	·79	·54	+ 112	·97	308·320	·97189	291·911
400	·83	·92	·65	+ 67	29·56	411·246	·97135	389·072
500	·56	·96	·71	+ 40	30·10	514·229	·97085	486·182
600	·18	·95	·75	+ 28	·62	617·265	·97037	583·243
700	3·37	·86	·76	+ 8	31·11	720·352	·96992	680·257
800	·31	·86	·76	+ 10	·60	823·488	·96948	777·226
900	·30	·87	·77	+ 10	32·08	926·672	·96904	874·152
1000	·29	·88	·78	+ 10	·56	1029·904	·96859	971·033
1200	·27	·90	·80		33·53	1236·513	·96772	1164·664

Stat. 81. 12. July 1910. 48° 2′ N. 39° 55′ W.

0	14·8	35·53	26·44	+ 312	26·44	0·0000	0·97424	0·0000
10	·80	·57	·47	+ 341	·51	10·2648	·97416	9·7420
25	·78	·63	·52	+ 338	·63	25·6634	·97406	24·3536
50	·68	·71	·61	+ 410	·84	51·3319	·97387	48·7026
75	·32	·74	·71	+ 369	27·06	77·0057	·97366	73·0467
100	13·93	·75	·80	+ 234	·26	102·6847	·97348	97·3859
150	·16	·69	·91	+ 80	·61	154·056	·97315	146·052
200	12·90	·67	·95	+ 64	·87	205·444	·97291	194·703
300	·83	·73	27·01	+ 59	28·39	308·257	·97243	291·970
400	·37	·68	·06	+ 101	·90	411·122	·97197	389·190
500	10·65	·37	·14	+ 143	29·46	514·040	·97145	486·360
600	8·48	·05	·26	+ 155	30·07	617·017	·97089	583·477
700	6·90	34·92	·39	+ 143	·69	720·055	·97032	680·538
800	5·75	·88	·51	+ 120	31·30	823·155	·96976	777·542
900	·13	·92	·61	+ 84	·88	926·314	·96922	874·491
1000	4·65	·94	·69		32·43	1029·530	·96871	971·387

Columns: Numerical Value of Argument a — $a = m$, Common Metres (Temp. °C, Salinity ‰, Density σ_t, Stability $10^8 E$) — $a = D$, Dynamic Metres (Density in situ $\sigma_{t,D}$, Pressure Decibars) — $a = p$, Pressure (Decibars) (Specific Volume in m.³ ton, Depth of Isobaric Surfaces Dynamic Metres)

Stat. **82.** 13. July 1910. 48° 26′ N. 37° 0′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	15·40	35·28	26·12	+ 423	26·12	0·0000	0·97451	0·0000
10	·35	·32	·16	+ 934	·21	10·2617	·97446	9·7450
25	·00	·40	·30	+1175	·41	25·6563	·97427	24·3604
50	14·15	·51	·59	+ 613	·82	51·3218	·97389	48·7122
75	13·13	·46	·74	+ 235	27·09	76·9958	·97364	73·0562
100	12·77	·44	·80	+ 246	·26	102·6752	·97348	97·3951
150	·93	·64	·92	+ 190	·62	154·047	·97314	146·060
200	·70	·70	27·01	+ 57	·93	205·436	·97285	194·710
300	11·93	·57	·06	+ 54	28·45	308·255	·97239	291·972
400	10·75	·34	·10	+ 116	·96	411·126	·97191	389·187
500	9·00	·08	·20	+ 174	29·54	514·051	·97137	486·351
600	7·18	34·92	·35	+ 163	30·18	617·037	·97079	583·459
700	6·05	·91	·49	+ 138	·80	720·086	·97022	680·509
800	5·26	·94	·62	+ 86	31·43	823·197	·96964	777·502
900	4·76	·96	·69	+ 47	·96	926·367	·96915	874·441
1000	·18	·97	·73	+ 20	32·48	1029·589	·96867	971·332
1200	·10	·95	·76		33·47	1236·184	·96778	1164·977

Stat. **83.** 14. July 1910. 48° 30′ N. 33° 55′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	15·8	35·53	26·22	— 363	26·22	0·0000	0·97445	0·0000
10	·96	·53	·19	+ 71	·24	10·2623	·97443	9·7444
25	·95	·54	·20	+1595	·31	25·6565	·97437	24·3604
50	14·20	·55	·59	+1589	·82	51·3207	·97389	48·7135
75	12·35	·57	·98	+ 185	27·33	76·9977	·97341	73·0547
100	11·92	·52	27·02	+ 125	·49	102·6829	·97327	97·3881
150	·48	·49	·08	+ 48	·78	154·065	·97300	146·045
200	·32	·48	·11	+ 20	28·04	205·460	·97276	194·689
300	10·90	·40	·13	+ 122	·53	308·289	·97232	291·942
400	9·33	·19	·23	+ 108	29·10	411·170	·97178	389·147
500	7·76	34·99	·33	+ 138	·68	514·109	·97124	486·297
600	6·47	·91	·44	+ 125	30·28	617·107	·97070	583·394
700	5·44	·88	·55	+ 97	·87	720·165	·97015	680·436
800	4·86	·90	·64	+ 78	31·45	823·281	·96962	777·425
900	·58	·95	·70	+ 27	·98	926·452	·96913	874·362
1000	·33	·94	·73	+ 18	32·51	1029·677	·96867	971·252
1200	3·90	·94	·75	+ 16	33·46	1236·274	·96779	1164·897
1400	·63	·90	·77	+ 12	34·44	1443·064	·96690	1358·366
1600	·48	·90	·78	+ 11	35·38	1650·046	·96605	1551·660
1800	·35	·90	·80		36·34	1857·218	·96518	1744·783

Stat. **85.** 15.—16. July 1910. 47° 58′ N. 31° 41′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	16·40	35·61	26·16	+ 127	26·16	0·0000	0·97451	0·0000
10	·38	·65	·18	+ 184	·22	10·2619	·97444	9·7447
25	·33	·67	·20	+ 311	·31	25·6559	·97437	24·3608
50	15·90	·64	·28	+1869	·51	51·3163	·97418	48·7176
75	13·50	35·56	26·70	+1201	27·05	76·9858	0·97367	73·0657
100	12·10	·58	27·04	+ 77	·50	102·6678	·97325	97·4022
150	11·47	·47	·07	+ 34	·77	154·050	·97301	146·059
200	·10	·40	·09	+ 82	28·02	205·444	·97277	194·703
300	10·55	·37	·16	+ 62	·56	308·273	·97228	291·955
400	9·35	·17	·21	+ 106	29·08	411·155	·97180	389·159
500	7·59	34·93	·30	+ 142	·65	514·092	·97127	486·312
600	6·25	·85	·42	+ 125	30·26	617·088	·97071	583·411
700	5·55	·88	·53	+ 106	·85	720·144	·97017	680·454
800	·02	·92	·63	+ 89	31·44	823·258	·96963	777·444
900	4·66	·97	·71	+ 47	·99	926·431	·96912	874·382
1000	·38	·98	·75	+ 17	32·50	1029·656	·96865	971·270
1200	3·97	·95	·77	+ 7	33·48	1236·254	·96777	1164·912
1400	·66	·91	·77		34·43	1443·045	·96690	1358·379

Stat. **86.** 16. July 1910. 47° 29′ N. 30° 20′ W.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	18·25	36·01	26·00	+ 705	26·00	0·0000	0·97466	0·0000
10	·03	·03	·07	+1513	·12	10·2606	·97455	9·7460
25	17·20	·06	·30	+1017	·41	25·6546	·97427	24·3621
50	16·20	·08	·55	+ 547	·78	51·3196	·97392	48·7143
75	15·28	35·98	·68	+ 432	27·02	76·9923	·97369	73·0594
100	14·63	·93	·78	+ 249	·24	102·6706	·97350	97·3993
150	13·78	·85	·91	+ 116	·61	154·042	·97315	146·066
200	·22	·77	·96	+ 66	·88	205·429	·97290	194·717
300	12·35	·62	27·02	+ 91	28·40	308·244	·97242	291·982
400	11·52	·52	·10	+ 42	·95	411·112	·97193	389·200
500	10·76	·38	·13	+ 91	29·45	514·032	·97147	486·369
600	·33	·39	·22	+ 157	30·01	617·005	·97095	583·490
700	9·40	·37	·36	+ 153	·62	720·037	·97039	680·557
800	8·00	·25	·49	+ 143	31·24	823·130	·96982	777·567
900	6·50	·12	·60	+ 114	·84	926·284	·96926	874·521
1000	5·28	·03	·68		32·41	1029·496	·96874	971·420

Stat. **87.** 17. July 1910. 46° 48′ N. 27° 44′ W. 2157 m.

Numerical Value of Argument a	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density in situ $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
0	18·75	35·84	25·74	+ 127	25·74	0·0000	0·97491	0·0000
10	·40	·74	·76	+2383	·81	10·2577	·97484	9·7487
25	16·85	·71	26·11	+3289	26·22	25·6480	·97445	24·3684
50	13·15	·71	·93	+ 227	27·16	51·3154	·97356	48·7185
75	12·80	·69	·98	+ 63	·33	76·9966	·97341	73·0555
100	·65	·67	27·00	+ 69	·46	102·6815	·97329	97·3892
150	·33	·63	·03	+ 48	·73	154·062	·97304	146·047
200	·02	·58	·05	+ 73	·98	205·454	·97282	194·694
300	11·42	·52	·12	+ 26	28·51	308·279	·97233	291·951
400	·10	·47	·14	+ 20	29·00	411·155	·97188	389·161
500	10·77	·41	·15	+ 56	·47	514·079	·97144	486·327
600	·03	·30	·20		·99	617·052	·97096	583·446

Numerical Value of Argument, *a*	*a* = *m*, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	*a* = *D*, Dynamic Metres: Density *in situ* $\sigma_{t,D}$	Pressure Decibars	*a* = *p*, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
700	8·57	35·17	27·34	+160	30·61	720·083	0·97040	680·514
800	7·33	·10	·47	+154	31·23	823·175	·96982	777·525
900	6·57	·07	·55	+ 98	·79	926·326	·96931	874·482
1000	·00	·06	·62	+ 81	32·34	1029·532	·96880	971·387
1200	4·98	·02	·72	+ 62	33·41	1236·107	·96784	1165·051
1400	·19	34·99	·78	+ 47	34·43	1442·891	·96691	1358·525
1600	3·75	·96	·80	+ 21	35·39	1649·873	·96603	1551·819

Stat. **88 A.** 18. July 1910. 45° 12′ N. 25° 46′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	18·9	35·80	25·68		25·68	0·0000	0·97496	0·0000
10	·73	·82	·72	+ 591	·76	10·2572	·97488	9·7492
25	·05	·84	·92	+1244	26·03	25·6457	·97463	24·3705
50	15·00	·84	26·63	+2871	·86	51·3069	·97385	48·7264
75	14·00	·81	·83	+ 787	27·18	76·9824	·97355	73·0688
100	13·44	·79	·93	+ 419	·39	102·6646	·97335	97·4050
150	12·84	·76	27·03	+ 205	·73	154·043	·97304	146·065
200	·42	·71	·08	+ 97	28·00	205·436	·97279	194·710
300	11·55	·55	·12	+ 52	·51	308·262	·97233	291·966
400	·00	·44	·14	+ 23	·99	411·137	·97188	389·176
500	10·57	·41	·19	+ 61	29·51	514·062	·97140	486·340
600	·00	·39	·28	+ 93	30·07	617·042	·97089	583·454
700	9·15	·27	·32	+ 63	·58	720·075	·97042	680·519
800	8·12	·18	·41	+111	31·16	823·162	·96988	777·531
900	7·25	·20	·56	+161	·79	926·309	·96931	874·494
1000	6·67	·22	·66	+110	32·36	1029·517	·96878	971·398
1200	5·63	·13	·72	+ 48	33·38	1236·091	·96786	1165·062
1400	4·50	34·99	·74	+ 32	34·37	1442·867	·96696	1358·543

Stat. **89.** 20 July 1910. 45° 55′ N. 22° 24′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	19·15	35·87	25·66		25·66	0·0000	0·97498	0·0000
10	·12	·86	·67	+ 6	·72	10·2569	·97493	9·7495
25	18·60	·83	·77	+ 736	·88	25·6439	·97478	24·3723
50	14·25	·77	26·75	+3892	26·98	51·3047	·97373	48·7287
75	13·27	·75	·95	+ 769	27·30	76·9833	·97344	73·0682
100	12·95	·73	·99	+ 205	·45	102·6677	·97330	97·4024
150	·50	·66	27·02	+ 77	·72	154·047	·97305	146·061
200	·10	·59	·05	+ 55	·97	205·439	·97282	194·708
300	11·43	·50	·11	+ 64	28·50	308·263	·97234	291·965
400	10·88	·47	·18	+ 85	29·04	411·141	·97184	389·174
500	·42	·44	·24	+ 66	·56	514·071	·97136	486·334
600	9·97	·41	·30	+ 63	30·09	617·054	·97088	583·445
700	·43	·39	·37	+ 85	·63	720·090	·97038	680·508
800	8·50	·36	·50	+143	31·24	823·184	·96982	777·518
900	7·40	·27	·60	+120	·82	926·337	·96928	874·472
1000	6·58	·21	·67	+ 90	32·37	1029·546	·96877	971·374

Stat. **90.** 21 July 1910. 46° 58′N. 19° 6′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	17·85	35·61	25·79		25·79	0·0000	0·97486	0·0000
10	·78	·61	·81	+ 176	·85	10·2582	·97479	9·7483
25	16·30	·61	26·16	+2362	26·27	25·6492	·97440	24·3672
50	12·54	·64	27·00	+3359	27·24	51·3181	·97349	48·7158
75	·10	·63	·08	+ 319	·43	77·0015	·97332	73·0509
100	11·85	·60	·10	+ 105	·57	102·6801	·97320	97·3824
150	·53	·56	·13	+ 64	·83	154·074	·97295	146·036
200	·35	·53	·14	+ 25	28·07	205·172	·97273	194·678
300	·12	·51	·17	+ 31	·56	308·303	·97228	291·928
400	10·87	·48	·19	+ 27	29·05	411·184	·97183	389·133
500	·63	·45	·21	+ 25	·53	514·113	·97138	486·293
600	·40	·42	·23	+ 23	30·02	617·091	·97094	583·408
700	·12	·41	·27	+ 47	·53	720·119	·97049	680·479
800	9·61	·42	·36	+104	31·08	823·200	·96996	777·501
900	·00	·44	·48	+129	·67	926·337	·96943	874·471
1000	8·43	·46	·59	+119	32·25	1029·534	·96884	971·386
1200	7·43	·37	·67	+ 54	33·28	1236·087	·96796	1165·070
1400	5·82	·18	·74	61	34·33	1442·849	·95699	1358·565

Stat. **91.** 22. July 1910. 47° 32′ N. 16° 38′ W. 4922 m.

a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	16·55	35·51	26·03		26·03	0·0000	0·97463	0·0000
10	·50	·51	·04	121	·08	10·2606	·97457	9·7460
25	15·15	·51	·35	+2065	·46	25·6547	·79422	24·3613
50	12·20	·51	·96	+2469	27·20	51·3254	·97353	48·7087
75	11·25	·51	27·14	+ 732	·49	77·0001	·97326	73·0135
100	10·96	·51	·20	+ 218	·67	102·6986	·97309	97·3728
150	·66	·51	·25	+ 113	·95	154·089	·97283	146·021
200	·45	·50	·28	+ 63	28.21	205·493	·97259	194·656
300	·08	·46	·32	+ 38	·72	308·340	·97213	291·832
400	9·70	·42	·35	+ 39	29·22	411·237	·97167	389·082
500	·40	·38	·37	+ 24	·70	514·183	·97122	486·226
600	·08	·35	·40	+ 35	30·21	617·179	·97076	583·325
700	8·78	·34	·44	+ 47	·71	720·225	·97031	680·378
800	·47	·39	·53	+ 95	31·27	823·324	·96978	777·383
900	·00	·43	·63	+113	·84	926·179	·96926	874·331
1000	6·96	·34	·71	+105	32·40	1029·692	·96875	971·231
1200	5·35	·13	·76	+ 46	33·44	1236·276	·96781	1164·830

Stat. **92.** 23. July 1910. 48° 29′ N. 13° 55′ W.

a	Temp. °C	Salinity ‰	Density σ_t	Stability 10^8 E	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume	Depth of Isobaric Surfaces
0	16·4	35·57	26·11		26.11	0·0000	0·97455	0·0000
10	·40	·56	·10	— 73	·15	10·2613	·97452	9·7453
25	·35	·54	·10	— 20	·21	25·6540	·97446	24·3626
50	12·05	·54	27·02	+3701	27·26	51·3224	·97347	48·7117
75	11·30	·52	·13	+ 455	·48	77·0067	·97327	73·0459
100	·08	·51	·18	+ 196	·65	102·6959	·97311	97·3757

Numerical Value of Argument *a*	*a* = *m*, Common Metres				*a* = *D*, Dynamic Metres		*a* = *p*, Pressure (Decibars)	
	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³/ton	Depth of Isobaric Surfaces Dynamic Metres
150	10·92	35·50	27·20	+ 46	27·90	154·085	0·97287	146·025
200	·80	·49	·21	+ 31	28·14	205·486	·97266	194·663
300	·50	·47	·25	+ 42	·65	308·325	·97220	291·906
400	·28	·44	·27	+ 20	29·14	411·215	·97175	389·103
500	·03	·41	·29	+ 25	·62	514·154	·97131	486·256
600	9·63	·39	·34	+ 59	30·14	617·142	·97083	583·363
700	·23	·41	·42	+ 89	·68	720·183	·97033	680·420
800	8·73	·44	·53	+ 114	31·27	823·281	·96979	777·426
900	·50	·52	·62	+ 104	·82	926·436	·96928	874·379
1000	7·20	·35	·69	+ 91	32·37	1029·646	·96877	971·282
1200	5·75	·19	·75	+ 56	33·41	1236·224	·96784	1164·942
1400	4·30	34·99	·77	+ 32	34·41	1443·006	·96692	1358·418

Stat. 93. 25. July 1910. 50° 3′ N. 11° 23′ W. 1257 m.

0	15·1	35·46	26·32		26·32	0·0000	0·97435	0·0000
10	·10	·46	·32	+ 4	·37	10·2635	·97430	9·7433
25	·05	·46	·33	+ 77	·44	25·6596	·97424	24·3573
50	11·60	·44	27·02	+2784	27·28	51·3311	·97346	48·7031
75	10·85	·50	·21	+ 750	·56	77·0167	·97319	73·0364
100	·74	·48	·22	+ 20	·69	102·7074	·97307	97·3646
150	·54	·44	·22	+ 13	·92	154·098	·97285	146·013
200	·38	·42	·23	+ 29	28·16	205·500	·97263	194·650
300	·30	·41	·24	+ 9	·64	308·340	·97221	291.891
400	·24	·43	·26	+ 29	29·12	411·228	·97176	389·090
500	·05	·44	·30	+ 45	·62	514·165	·97130	486·242
600	9·79	·43	·34	+ 42	30·13	617·153	·97084	583·349
700	·36	·41	·40	+ 65	·66	720·193	·97035	680·408
800	·00	·44	·48	+ 90	31·21	823·287	·96985	777·418
900	8·68	·47	·56	+ 82	·76	926·436	·96934	874·377
1000	·27	·47	·62	+ 74	32·28	1029·638	·96885	971·287
1200	6·30	·26	·74	+ 86	33·38	1236·205	·96786	1164·958

Stat. 97. 4 August 1910. 56° 15′ N. 8° 28′ W. 139 m.

0	13·55	34·88	26·20		26·20	0·0000	0·97447	0·0000
10	·27	·95	·32	+1120	·37	10·2628	·97430	9·7439
25	11·88	35·16	·75	+2931	·86	25·6621	·97384	24·3549
50	9·37	·28	27·30	+2172	27·54	51·3422	·97321	48·6930
75	8·84	·25	·36	+ 258	·71	77·0329	·97305	73·0212
100	·60	·20	·36	− 1	·83	102·7272	·97294	97·3460

Stat. 98. 5. August 1910. 56° 33′ N. 9° 30′ W.

0	14·35	35·23	26·31		26·31	0·0000	0·97436	0·0000
10	·10	·24	·37	+ 613	·42	10·2637	·97426	9·7431
25	13·02	·29	·63	+1758	·74	25·6624	·97396	24·3547
50	10·89	·37	27·10	+1903	27·34	51.3385	·97340	48·6967
75	·25	·35	·20	+ 401	·55	77·0246	·97320	73·0291

Numerical Value of Argument *a*	*a* = *m*, Common Metres				*a* = *D*, Dynamic Metres		*a* = *p*, Pressure (Decibars)	
	Temp. °C	Salinity ‰	Density σ_t	Stability $10^8 E$	Density *in situ* $\sigma_{t,D}$	Pressure Decibars	Specific Volume in m.³/ton	Depth of Isobaric Surfaces Dynamic Metres
100	9·87	35·34	27·26	+ 237	27·73	102·7157	0·97304	97·3570
150	·56	·34	·31	+ 109	28·01	154·109	·97277	146·002
200	·41	·35	·35	+ 69	·28	205·517	·97252	194·634
300	·30	·35	·36	+ 21	·76	308·369	·97209	291·865
400	·21	·34	·37	+ 10	29·23	411·269	·97164	389·051
500	·07	·33	·39	+ 19	·72	514·217	·97119	486·192
600	8·82	·33	·42	+ 45	30·22	617·214	·97074	583·289
700	·53	·31	·45	+ 37	·72	720·262	·97029	680·340
800	·18	·27	·48	+ 31	31·22	823·359	·96983	777·346
900	7·70	·23	·52	+ 52	·74	926·507	·96936	874·305
1000	·14	·20	·58	+ 71	32·27	1029·708	·96887	971·216

Stat. 99. 6 August 1910. 57° 45′ N. 13° 40′ W. 149 m.

0	12·45	35·24	26·71		26·71	0·0000	0·97398	0·0000
10	·34	·26	·74	+ 373	·79	10·2675	·97391	9·7394
25	·00	·27	·82	+ 497	·93	25·6704	·97378	24·3470
50	10·77	·28	27·05	+ 958	27·29	51·3482	·97345	48·6873
75	8·76	·27	·39	+1354	·74	77·0361	·97302	73·0180
100	·56	·29	·43	+ 193	·90	102·7317	·97287	97·3416

Stat. 100. 6. August 1910. 57° 48′ N. 12° 43′ W. 1530 m.

0	13·2	35·27	26·58		26·58	0·0000	0·97411	0·0000
10	·10	·30	·62	+ 440	·67	10·2663	·97402	9·7407
25	12·88	·35	·70	+ 558	·81	25·6674	·97389	24·3499
50	10·71	·31	27·08	+1545	27·32	51·3441	·97342	48·6913
75	9·84	·31	·24	+ 618	·59	77·0305	·97316	73·0235
100	·54	·31	·29	+ 208	·76	102·7275	·97301	97·3506
150	·23	·32	·35	+ 122	28·06	154·118	·97273	145·994
200	·02	·32	·38	+ 72	·32	205·527	·97249	194·625
300	8·68	·30	·42	+ 43	·82	308·385	·97202	291·850
400	·46	·28	·44	+ 23	29·31	411·291	·97157	389·030
500	·33	·27	·45	+ 16	·79	514·246	·97113	486·165
600	·15	·26	·47	+ 24	30·28	617·250	·97069	583·256
700	7·85	·24	·50	+ 36	·78	720·304	·97024	680·302
800	·48	·20	·53	+ 32	31·29	823·407	·96977	777·302
900	·05	·18	·57	+ 56	·80	926·562	·96929	874·255
1000	6·53	·17	·63	+ 76	32·33	1029·769	·96880	971·159
1200	5·17	·04	·71	+ 55	33·39	1236·342	·96786	1164·825
1400	4·49	·01	·76	+ 40	34·39	1443·121	·96694	1358·304

Stat. 101. 7. August 1910. 57° 41′ N. 11° 48′ W. 1853 m.

0	13·4	35·32	26·57		26·57	0·0000	0·97412	0·0000
10	·15	·33	·63	+ 595	·68	10·2663	·97401	9·7407
25	12·05	·34	·86	+1514	·97	25·6687	·97374	24·3487
50	10·35	·35	27·19	+1305	27·43	51·3487	·97331	48·6868
75	9·80	·34	·27	+ 356	·62	77·0369	·97314	73·0174

Numerical Value of Argument a	a = m, Common Metres: Temp. °C	Salinity ‰	Density σ_t	Stability 10^8E	a = D, Dynamic Metres: Density in situ σ_t, D	Pressure Decibars	a = p, Pressure (Decibars): Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
				+ 157				
100	9·53	35·33	27·30	+ 90	27·77	102·7294	0·97300	97·3441
150	·27	·33	·35	+ 74	28·06	154·125	·97273	145·987
200	·10	·34	·39	+ 28	·33	205·535	·97248	194·618
300	8·90	·33	·41	+ 15	·81	308·392	·97203	291·843
400	·73	·31	·42	+ 12	29·29	411·297	·97159	389·024
500	·58	·29	·43	+ 12	·77	514·250	·97115	486·160
600	·43	·27	·44	+ 33	30·25	617·251	·97072	583·254
700	·20	·26	·46	+ 48	·73	720·300	·97028	680·303
800	7·88	·25	·51	+ 56	31·26	823·400	·96979	777·307
900	·45	·23	·55	+ 65	·77	926·552	·96932	874·262
1000	6·92	·20	·61	+ 63	32·30	1029·756	·96883	971·170
1200	5·70	·11	·70	+ 49	33·37	1236·323	·96788	1164·841
1400	4·61	·02	·76	+ 44	34·39	1443·101	·96694	1358·323
1600	3·86	34·99	·81	+ 30	35·39	1650·079	·96603	1551·619
1800	·40	·98	·85		36·39	1857·257	·96514	1744·736

Stat. **103.** 10. August 1910. 60° 26′ N. 2° 34′ W. 159 m.

0	13·15	34·98	26·30	+1313	26·30	0·0000	0·97437	0·0000
10	·19	35·08	·43	+1978	·48	10·2639	·97420	9·7429
25	12·25	·22	·73	+2160	·84	25·6639	·97386	24·3533
50	9·60	·29	27·26	+ 311	27·50	51·3432	·97325	48·6920
75	·09	·28	·34	+ 295	·69	77·0331	·97307	73·0209
100	8·64	·28	·41	+ 30	·88	102·7278	·97289	97·3453
150	·60	·29	·43		28·14	154·128	·97265	145·984

Stat. **104.** 10. August 1910. 60° 35′ N. 3° 20′ W. 234 m.

0	13·30	35·21	26·51	1112	26·51	0·0000	0·97417	0·0000
10	12·83	·23	·62	+1042	·67	10·2659	·97402	9·7410
25	·16	·26	·78	+1929	·89	25·6677	·97382	24·3497
50	9·88	·34	27·26	+ 326	27·50	51·3476	·97325	48·6880
75	·50	·36	·34	+ 48	·69	77·0375	·97307	73·0168
100	·34	·34	·35	+ 65	·82	102·7315	·97295	97·3420
150	·15	·34	·38	+ 22	28·09	154·129	·97270	145·983
200	·09	·34	·39		·33	205·540	·97248	194·613

Stat. **105.** 10. August 1910. 60° 45′ N. 3° 50′ W. 670 m.

0	12·75	35·17	26·59	+ 401	26·59	0·0000	0·97410	0·0000
10	·55	·17	·63	+1500	·68	10·2664	·97401	9·7406
25	11·38	·17	·85	+1069	·96	25·6687	·97375	24·3487
50	9·89	·17	27·12	+ 540	27·36	51·3228	·97338	48·6878
75	·09	·17	·25	+ 561	·60	77·0098	·97315	73·0194
100	8·21	·17	·39	+ 143	·86	102·7031	·97291	97·3451
150	7·80	·18	·46	+ 62	28·17	154·104	·97263	145·984
200	·60	·18	·49	+ 70	·43	205·519	·97239	194·609
300	·09	·17	·56	+ 135	·98	308·389	·97188	291·822
400	5·59	35·07	27·68	+ 203	29·58	411·318	0·97133	388·982
500	2·77	34·90	·85	+ 192	30·26	514·310	·97070	486·083
600	0·63	·89	28·00		·93	617·369	·97008	583·122

Stat. **106.** 10. and 11. August 1910. 60° 54′ N. 4° 28′ W. 1140 metres.

0	13·05	35·00	26·40	+ 620	26·40	0·0000	0·97428	0·0000
10	12·82	·02	·46	+2214	·51	10·2646	·97417	9·7423
25	11·51	·12	·79	+1961	·90	25·6652	·97381	24·3521
50	9·60	·31	27·28	+ 380	27·52	51·3455	·97323	48·6900
75	·13	·33	·37	+ 22	·72	77·0361	·97304	73·0183
100	·10	·33	·38	+ 29	·85	102·7308	·97292	97·3428
150	8·97	·32	·39	+ 20	28·10	154·130	·97269	145·983
200	·82	·30	·40	+ 29	·34	205·541	·97247	194·612
300	·61	·29	·42	+ 25	·82	308·399	·97202	291·836
400	·33	·26	·44	+ 81	29·31	411·306	·97157	389·016
500	7·39	·17	·52	+ 283	·87	514·265	·97106	486·147
600	4·75	·05	·76	+ 213	30·62	617·290	·97037	583·218
700	1·52	34·86	·91	+ 148	31·30	720·386	·96975	680·224
800	0·10	·89	28·03	+ 46	·94	823·548	·96915	777·169
900	—0·38	·90	·07	+ 20	32.47	926·769	·96869	874·061
1000	— ·64	·90	·08		·97	1030·011	·96825	970·908

Stat. **107.** 11. August 1910. 61° 4′ N. 5° 5′ W. 730 m.

0	12·0	35·28	26·82	+ 80	26·82	0·0000	0·97388	0·0000
10	11·92	·27	·83	+ 180	·88	10·2685	·97382	9·7385
25	·70	·25	·86	1261	·97	25·6724	·97374	24·3452
50	9·98	·25	27·17	526	27·41	51·3522	·97333	48·6835
75	·21	·25	·30	+ 196	·65	77·0406	·97311	73·0139
100	8·72	·21	·34	+ 158	·81	102·7339	·97296	97·3397
150	·28	·22	·42	+ 130	28·13	154·132	·97266	145·980
200	7·87	·22	·48	+ 111	·42	205·546	·97240	194·607
300	6·83	·16	·58	+ 138	29·00	308·417	·97186	291·820
400	5·40	·08	·71	+ 241	·61	411·348	·97130	388·977
500	1·85	34·88	·90	+ 151	30·32	514·345	·97064	486·074
600	0·13	·89	28·03	+ 62	·97	617·409	·97004	583·108
700	—0·51	·91	·08		31·51	720·533	·96957	680·088

Stat. **108.** 11. August 1910. 61° 13′ N. 5° 47′ W. 249 m.

0	11·9	35·24	26·81	+ 93	26·81	0·0000	0·97389	0·0000
10	·73	·21	·82	+ 291	·87	10·2684	·97383	9·7386
25	·46	·20	·86	+ 676	·97	25·6723	·97374	24·3453
50	10·54	·20	27·03	+ 691	27·27	51·3503	·97316	48·6853
75	9·59	·21	·20	+ 916	·55	77·0356	·97320	73·0185
100	8·53	·28	·43	+ 92	·90	102·7288	·97287	97·3443
150	7·89	·21	·47	+ 151	28·18	154·131	·97262	145·982
200	·13	·16	·54		·48	205·547	·97233	194·605

Numerical Value of Argument *a*	*a* Temp. °C	*m*, Common Metres Salinity ‰	Density σ_t	Stability 10^8 E	*a* = *D*, Dynamic Metres Density *in situ* $\sigma_{t,D}$	Pressure Decibars	*a* *p*, Pressure (Decibars) Specific Volume in m.³ ton	Depth of Isobaric Surfaces Dynamic Metres
Stat. 109. 11. August 1910. 61° 22′ N. 6° 24′ W. 228 m.								
0	10·85	35·17	26·95		26·95	0·0000	0·97376	0·0000
10	·50	·12	·98	+ 240	27·03	10·2699	·97368	9·7372
25	9·77	·10	27·09	+ 745	·20	25·6767	·97353	24·3412
50	8·90	·15	·27	+ 732	·51	51·3606	·97324	48·6758
75	·32	·16	·37	+ 402	·72	77·0511	·97304	73·0042
100	·29	·15	·37	11	·84	102·7456	·97293	97·3288
150	·28	·16	·38	+ 20	28·09	154·130	·97270	145·970
200	7·95	·14	·41	+ 73	·35	205·541	·97246	194·599
Stat. 110. 11. August 1910. 61° 39′ N. 5° 57′ W. 170 m.								
0	11·05	35·15	26·90		26·90	0·0000	0·97380	0·0000
10	10·95	·15	·92	+ 185	·97	10·2694	·97373	9·7377
25	·53	·16	27·00	+ 558	27·11	25·6750	·97361	24·3427
50	9·49	·17	·19	+ 749	·43	51·3568	·97331	48·6791
75	8·68	·16	·31	+ 502	·66	77·0455	·97310	73·0092
100	7·83	·16	·44	+ 529	·91	102·7402	·97287	97·3337
150	·60	·16	·48	+ 71	28·19	154·143	·97261	145·971
Stat. 111. 12. August 1910. 61° 32′ N. 5° 16′ W. 300 m.								
0	11·75	35·19	26·80		26·80	0·0000	0·97390	0·0000
10	·22	·17	·88	+ 838	·93	10·2687	·97377	9·7384
25	9·84	·16	27·12	+1588	27·23	25·6749	·97350	24·3428
50	8·70	·17	·32	+ 786	·56	51·3599	·97319	48·6764
75	·17	·18	·41	+ 366	·76	77·0514	·97300	73·0037
100	7·58	·16	·48	+ 298	·95	102·7479	·97283	97·3265
150	6·95	·12	·54	+ 123	28·25	154·153	·97255	145·961
200	·45	·12	·61	+ 143	·55	205·573	·97226	194·581
300	·16	·12	·65	+ 42	29·07	308·454	·97179	291·783
Stat. 112. 12. August 1910. 61° 24′ N. 4° 34′ W. 560 m.								
0	11·3	35·17	26·87		26·87	0·0000	0·97383	0·0000
10	10·90	·17	·94	+ 734	·99	10·2693	·97372	9·7377
25	·29	·17	27·05	+ 730	27·16	25·6755	·97357	24·3423
50	9·29	·21	·25	+ 807	·49	51·3587	·97326	48·6776
75	8·19	·19	·41	+ 643	·76	77·0494	·97300	73·0057
100	7·89	·19	·46	+ 186	·93	102·7455	·97285	97·3287
150	·68	·21	·50	+ 96	28·21	154·149	·97259	145·965
200	·54	·20	·52	+ 28	·46	205·566	·97236	194·588
300	·07	·15	·55	+ 32	·97	308·437	·97189	291·800
400	6·29	·12	·63	+ 91	29·53	411·362	·97137	388·963
500	1·09	34·88	·96	+ 394	30·40	514·359	·97056	486·060
Stat. 113. 12. August 1910. 61° 16′ N. 3° 50′ W. 1080 m.								
0	11·65	35·20	26·83		26·83	0·0000	0·97387	0·0000
10	·30	·19	·88	+ 579	·93	10·2688	·97377	9·7382
25	10·41	·19	27·05	+1076	27·16	25·6745	·97356	24·3432
50	9·00	·19	·29	+ 961	·53	51·3582	·97322	48·6779
75	8·45	·19	·37	+ 354	·72	77·0489	·97304	73·0061
100	·35	·19	·39	+ 65	·86	102·7487	·97291	97·3304
150	7·90	35·18	27·45	+ 126	28·16	154·149	0·97264	145·969
200	·43	·17	·51	+ 128	·45	205·564	·97237	194·594
300	6·45	·09	·58	+ 82	29·00	308·437	·97186	291·805
400	3·93	·00	·81	+ 256	·73	411·373	·97118	388·957
500	1·12	34·83	·92	+ 144	30·36	514·378	·97060	486·046
600	0·19	·91	28·04	+ 137	·98	617·445	·97004	583·078
700	— ·27	·91	·07	+ 34	31·49	720·569	·96958	680·059
800	— ·52	·90	·07	+ 10	·99	823·743	·96913	776·994
Stat. 114. 12. and 13. August 1910. 61° 8′ N. 3° 14′ W. 1047 m.								
0	12·35	35·17	26·67		26·67	0·0000	0·97402	0·0000
10	11·95	·17	·75	+ 775	·80	10·2673	·97390	9·7396
25	10·61	·18	27·00	+1707	27·11	25·6717	·97361	24·3458
50	8·38	·17	·37	+1469	·61	51·3558	·97314	48·6801
75	7·77	·17	·46	+ 375	·81	77·0486	·97295	73·0063
100	·49	·16	·49	+ 138	·96	102·7458	·97282	97·3284
150	·15	·16	·54	+ 101	28·25	154·151	·97255	145·962
200	6·80	·16	·59	+ 102	·53	205·571	·97228	194·583
300	5·27	·07	·72	+ 139	29·15	308·455	·97172	291·783
400	2·05	34·84	·86	+ 177	·80	411·402	·97112	388·925
500	0·82	·85	·95	+ 115	30·39	514·412	·97057	486·009
600	·40	·87	28·00	+ 50	·93	617·478	·97008	583·042
700	—0·05	·89	·04	+ 50	31·46	720·597	·96960	680·025
800	— ·50	·89	·06	+ 34	·98	823·769	·96914	776·962
900	— ·77	·89	·08	+ 20	32·49	926·993	·96869	873·853
1000	— ·85	·89	·08	+ 6	·97	1030·266	·96826	970·670
Stat. 115. 13. and 14. August 1910. 61° 0′ N. 2° 41′ W. 580 m.								
0	12·7	35·21	26·63		26·63	0·0000	0·97406	0·0000
10	·03	·18	·74	+1083	·79	10·2671	·97391	9·7398
25	10·20	·15	27·05	+2080	27·16	25·6718	·97356	24·3458
50	8·60	·14	·31	+1040	·55	51·3557	·97320	48·6803
75	·10	·16	·40	+ 376	·75	77·0470	·97301	73·0079
100	7·90	·18	·45	+ 187	·92	102·7430	·97286	97·3311
150	·52	·19	·51	+ 131	28·22	154·146	·97258	145·967
200	·04	·15	·55	+ 80	·49	205·564	·97232	194·589
300	5·08	·02	·70	+ 166	29·13	308·445	·97174	291·792
400	2·32	34·87	·86	+ 192	·79	411·391	·97112	388·935
500	0·85	·86	·96	+ 122	30·40	514·401	·97056	486·019
Stat. 116. 14. August 1910. 60° 52′ N. 2° 1′ W. 125 m.								
0	12·6	35·12	26·58		26·58	0·0000	0·97411	0·0000
10	·50	·16	·63	+ 510	·68	10·2663	·97401	9·7406
25	11·94	·25	·81	+ 1196	·92	25·6684	·97379	24·3491
50	9·87	·33	27·25	+1766	27·49	51·3485	·97326	48·6871
75	·17	·34	·37	+ 507	·72	77·0387	·97304	73·0157
100	8·89	·33	·41	+ 155	·88	102·7338	·97289	97·3397

Table IV. Anomalies of Specific Volume, and of Depth of Isobaric Surfaces.

A. Anomalies of Specific Volume. $10^5 (\alpha - \alpha_{35,0,p})$

p d-bars	$10^5\ \alpha_{35,0,p}$	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	18 A	p d-bars
0	97264	85	85	81	82	111	77	85	90	87	109	99	132	291	139	140	165	0
10	97260	78	81	78	83	108	76	84	88	85	105	96	112	212	139	139	159	10
25	97253	78	81	80	85	109	78	85	89	86	99	96	113	146	140	140	109	25
50	97242	77	79	79	82	98	76	85	88	85	90	92	106	106	119	122	— 50	50
75	97230	79	80	80	83		78	86	89	86	90	92	99	99	114	117	— 74	75
100	97219	79	80	80	83		78	87	89	87	89	91	95		110	115	— 81	100
150	97197		81	81	82		77	84	88	87	90	91	94		100	110	— 84	150
200	97174				84			83	90	89	92	93				108	— 82	200
300	97129				87			85	92	92	94	93				103	— 79	300
400	97084				89			86	94	93	94	92				98	— 76	400
500	97040				87			85	94	94	93	90				90		500
600	96995				83			85	94	95	94	92				77		600
700	96951				78			81	90	94	92	92				64		700
800	96907				75			73	80	87	83					52		800
900	96863							67	69	80	74					46		900
1000	96819							60	63	73	68					48		1000
1200	96732							54			60					53		1200
1400	96645							48			55					53		1400
1600	96559										51					50		1600
1800	96473										47							1800
2000	96388										44							2000

B. Anomalies of Depth of Isobaric Surfaces. $10^4 (D - D_{35,0,p})$ dyn.metres

p d-bars	$10^4\ D_{35,0,p}$	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	18 A	p d-bars
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	97262	81	83	80	82	109	77	85	89	86	107	98	122	252	139	140	162	10
25	243147	198	204	198	208	272	192	211	221	214	260	241	290	520	348	348	362	25
50	486266	391	404	396	417	530	384	423	442	426	498	476	564	834	671	675	436	50
75	729356	585	602	594	622		575	636	663	639	722	705	819	1090	962	973	280	75
100	972417	782	801	793	829		770	852	884	855	945	933	1061		1240	1263	86	100
150	1458457		1203	1196	1242		1157	1278	1327	1288	1393	1388	1534		1763	1825	— 328	150
200	1944384				1657			1696	1772	1725	1848	1848				2369	— 745	200
300	2915899				2512			2536	2682	2625	2778	2778				3421	—1552	300
400	3886964				3392			3391	3609	3545	3718	3701				4426	—2330	400
500	4857584				4272			4246	4547	4478	4650	4836				5366		500
600	5827759				5119			5096	5487	5423	5580	5746				6199		600
700	6797489				5922			5923	6404	6365	6508	6666				6899		700
800	7766779				6684			6691	7249	7265	7383					7474		800
900	8735629							7388	7989	8098	8165					7959		900
1000	9704039							8021	8647	8860	8870					8426		1000
1200	11639549							9156			10145					9431		1200
1400	13573319							10171			11295					10486		1400
1600	15505359										12350					11511		1600
1800	17435679										13325							1800
2000	19364289										14235							2000

Stations

A. Anomalies of Specific Volume. $10^5 (\alpha - \alpha_{35,\,0,\,p})$.

p d-bars	19 A	20	22	23	25 B	26	27	28	29	30	31	32	33	34	35	38	39 A	40	44	p d-bars
0	132	150	184	168	162	175	155	159	166	154	166	179	153	156	184	214	190	174	163	0
10	129	148	183	166	163	178	155	157	168	155	168	178	152	168	186	185	183	178	165	10
25	118	137	159	153	165	127	153	153	171	159	156	169	149	179	184	151	173	179	171	25
50	91	113	133	127	131	106	135	146	130	131	136	121	137	150	162	141	165	157	169	50
75	83	112	123	121	123		125	131	124	130	126	107	126	142	146	141	163	148	154	75
100	69	110	117	117	118		121	124	121	129	116	104	117	139	140		161	142	149	100
150	— 66		116	116	111		117	120	115	122	110			138	134		150	130	146	150
200	— 79		114	114	109		116	117	112	117				135	130		140	118	142	200
300	— 79		103	106	108		110	109	110	109				118				113	124	300
400	— 77		99	105	107		104	106	103	102				110				112	119	400
500	— 75		94	98	104			103	96	97				101				103	110	500
600	— 71		89	92	97			97	90	92				94				95	102	600
700	— 69		84	85	85			90	82	85				87				87	94	700
800	— 66		80	79	77			73	74	74				80				79	84	800
900	— 63			71	71				69	69				74				70	75	900
1000	— 60			67	67				66	63				66				66	68	1000
1200				62	59														58	1200
1400					52														52	1400
1600					49														48	1600
1800					48														46	1800
2000					47														42	2000

B. Anomalies of Depth of Isobaric Surfaces. $10^4 (D - D_{35,\,0,\,p})$ dyn.metres.

p d-bars	19 A	20	22	23	25 B	26	27	28	29	30	31	32	33	34	35	38	39 A	40	44	p d-bars
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	131	149	183	167	163	177	155	158	167	155	167	178	152	162	185	200	186	176	164	10
25	316	361	439	405	408	405	385	389	421	390	410	438	378	422	462	451	453	443	415	25
50	576	673	804	755	778	695	744	762	797	752	773	800	734	834	894	815	875	862	839	50
75	793	955	1123	1064	1096		1068	1108	1114	1078	1100	1084	1062	1199	1278	1167	1284	1243	1242	75
100	983	1232	1423	1360	1397		1376	1426	1421	1401	1401	1348	1365	1550	1636		1689	1605	1621	100
150	989	·	2006	1943	1970		1969	2035	2009	2028	1965			2242	2321		2467	2284	2358	150
200	626		2581	2517	2518		2549	2626	2575	2624				2923	2981		3190	2902	3077	200
300	— 167		3666	3614	3601		3674	3756	3683	3754				4183				4054	4402	300
400	— 952		4673	4667	4673		4739	4829	4743	4809				5326				5179	5614	400
500	—1717		5636	5677	5723			5869	5735	5801				6378				6252	6757	500
600	—2452		6551	6624	6726			6864	6663	6741				7351				7237	7812	600
700	—3154		7416	7509	7633			7796	7518	7621				8253				8142	8787	700
800	—3832		8233	8327	8438			8611	8295	8414				9083				8969	9672	800
900	—4482			9074	9176				9010	9129				9848				9714	10464	900
1000	—5102			9762	9863				9685	9789				10546				10394	11177	1000
1200				11047	11118														12427	1200
1400					12223														13522	1400
1600					13228														14522	1600
1800					14198														15462	1800
2000					15143														16337	2000

A. Anomalies of Specific Volume. $10^5 (\alpha - \alpha_{35,0,p})$

p d-bars	46	49C	50	51	53	57	58	59	60	63	64	65	66	67 & 67 A	68	69	70	70A	71	p d-bars
0	166	184	197	216	209	199	212	199	222	269	277	264	345	259	265	221	318	339	325	0
10	168	183	198	216	211	197	211	187	222	264	263	254	315	258	264	222	312	327	311	10
25	172	183	199	217	211	187	208	174	220	202	247	239	263	257	263	220	258	279	265	25
50	164	176	183	189	176	149	174	162	218	174	200	220	173	251	244	157	140	148	130	50
75	151	158	168	170	159	139	151	149	151	161	173	162	167	230	210	151	117	123	113	75
100	148	151	163	163	154	135	141	143	147	159	169	157	125	214	184	145	107	111	109	100
150	147	150	158	158	145	131	133	139	144	155	164	155	109	174	174	135	95	96	105	150
200	145	150	156	157	138	129	129	134	141	154	164	155	102	165	172	127	86	91		200
300	131	139	146	148	127	123	124		134	149	161	153	90	154	167	109	67			300
400	119	125	136	141	120	117	117		125	144	151	150	74	144	164	89	55			400
500	111	112	122	128	111	110	110		114	131	134	144	71	123	156	70	47			500
600	105	101	112	115	99	106	104		101	116	126	134	54	98	137	55	44			600
700	96	97	103	104	92	100	97		89	97	114	121	49	87	118	52	43			700
800	82	87	92	90	83	90			74	74	95	102	46	73	94	49	42			800
900	72	75	82	79	68	78			61	54	76	84	45	55	71	47	43			900
1000	65	65	72	69	61	70			56	49	64	69	44	50	59	46	43			1000
1200	54	52	59	59	55	61			50	50	54	54	43		52	43				1200
1400	49	48	53	52	53	56			47	49	50	50	43		45	43				1400
1600	47	47	50	49	45	50			44	47	47	49	44			44				1600
1800	45	45	48	47		45			45	46	47	49	45			46				1800
2000	44		46	45					46	45	47	48								2000

B. Anomalies of Depth of Isobaric Surfaces. $10^4 (D - D_{35,0,p})$ dyn.metres

p d-bars	46	49C	50	51	53	57	58	59	60	63	64	65	66	67 & 67 A	68	69	70	70A	71	p d-bars
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	167	183	197	216	210	198	211	193	222	266	270	259	330	258	265	222	315	333	318	10
25	422	457	495	540	526	485	525	464	553	615	652	628	763	644	660	553	742	787	750	25
50	841	906	971	1048	1009	904	1001	883	1100	1085	1211	1201	1307	1278	1294	1023	1238	1320	1244	50
75	1234	1322	1410	1496	1427	1262	1406	1271	1560	1502	1676	1678	1731	1879	1861	1406	1558	1658	1547	75
100	1608	1709	1823	1912	1816	1604	1770	1635	1932	1902	2102	2077	2095	2434	2353	1776	1838	1950	1824	100
150	2346	2460	2626	2715	2561	2266	2454	2339	2658	2685	2935	2856	2680	3403	3247	2474	2343	2468	2359	150
200	3076	3209	3409	3502	3268	2915	3108	3020	3369	3455	3754	3629	3208	4248	4110	3128	2794	2935		200
300	4456	4654	4914	5027	4590	4172	4370		4741	4968	5376	5167	4168	5838	5800	4308	3556			300
400	5703	5974	6322	6472	5823	5370	5573		6031	6433	6936	6679	4988	7323	7450	5296	4166			400
500	6851	7156	7609	7817	6975	6502	6705		7224	7808	8359	8149	5660	8655	9045	6088	4674			500
600	7928	8216	8777	9032	8023	7577	7770		8299	9040	9656	9539	6233	9760	10505	6711	5126			600
700	8931	9204	9849	10125	8978	8602	8773		9246	10100	10854	10812	6748	10685	11775	7241	5559			700
800	9821	10124	10819	11092	9850	9547			10056	10950	11896	11922	7223	11485	12830	7741	5979			800
900	10588	10934	11687	11935	10600	10382			10726	11588	12751	12847	7678	12123	13650	8218	6399			900
1000	11271	11631	12457	12672	11240	11120			11309	12103	13449	13609	8120	12645	14295	8683	6826			1000
1200	12461	12796	13762	13947	12395	12430			12369	13093	14624	14834	8985		15400	9573				1200
1400	13486	13796	14872	15052	13470	13595			13334	14078	15659	15869	9845		16370	10428				1400
1600	14441	14741	15892	16057	14445	14645			14239	15028	16624	16854	10715			11293				1600
1800	15361	15656	16862	17012		15590			15129	15953	17564	17824	11605			12193				1800
2000	16246		17792	17932					16034	16863	18504	18789								2000

Stations

A. Anomalies of Specific Volume. $10^5 (\alpha - \alpha_{35,0,p})$.

p d-bars	72	73	74	76	77	79	80	81	82	83	85	86	87	88 A	89	90	91	92	93	p d-bars
0	326	303	273	210	217	224	196	160	190	181	187	202	227	232	234	222	199	191	171	0
10	323	288	269	199	208	199	195	156	186	183	184	195	224	228	233	219	197	192	170	10
25	320	277	261	178	202	163	193	153	174	184	184	174	192	210	225	187	169	193	171	25
50	184	168	180	103	103	93	161	145	147	147	176	150	114	143	131	107	111	105	124	50
75	180		163	81	86	78	117	136	134	111	137	139	111	125	114	102	96	97	89	75
100			154	68	74	69	102	129	129	108	106	131	110	116	111	101	90	92	88	100
150			134	55	59	56	93	118	117	103	104	118	107	107	108	98	86	90	88	150
200				51		51	86	117	111	102	103	116	108	105	108	99	85	92	89	200
300				47			60	114	110	103	99	113	104	104	105	99	84	91	92	300
400				41			51	113	107	94	96	109	104	104	100	99	83	91	92	400
500							45	105	97	84	87	107	104	100	96	98	82	91	90	500
600							42	94	84	75	76	100	101	94	93	99	81	88	89	600
700							41	81	71	64	66	88	89	91	87	98	80	82	84	700
800							41	69	57	55	56	75	75	81	75	89	71	72	78	800
900							41	59	52	50	49	63	68	68	65	80	63	65	71	900
1000							40	52	48	48	46	55	61	59	58	70	56	58	66	1000
1200							40		46	47	45		52	54		64	49	52	54	1200
1400										45	45		46	51		54		47		1400
1600										46			44							1600
1800										45										1800
2000																				2000

B. Anomalies of Depth of Isobaric Surfaces. $10^4 (D - D_{35,0,p})$ dyn.metres.

p d-bars	72	73	74	76	77	79	80	81	82	83	85	86	87	88 A	89	90	91	92	93	p d-bars
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	325	296	271	205	213	212	196	158	188	182	185	198	225	230	233	221	198	191	171	10
25	806	719	668	487	520	483	486	389	457	457	461	474	537	558	576	525	472	479	426	25
50	1435	1274	1220	839	900	801	928	761	857	869	911	878	919	999	1021	892	822	851	768	50
75	1889		1648	1069	1136	1015	1275	1111	1207	1191	1301	1239	1200	1333	1327	1154	1079	1104	1008	75
100			2044	1255	1335	1198	1548	1442	1534	1464	1605	1576	1475	1634	1607	1407	1311	1340	1229	100
150			2763	1562	1668	1511	2034	2060	2148	1991	2129	2198	2016	2190	2153	1902	1750	1795	1669	150
200				1827		1778	2479	2646	2718	2502	2645	2782	2553	2720	2692	2392	2176	2248	2111	200
300				2315			3207	3799	3821	3522	3655	3925	3608	3762	3752	3377	3021	3161	3014	300
400				2750			3759	4931	4903	4502	4627	5032	4645	4797	4774	4362	3856	4068	3931	400
500							4234	6019	5923	5389	5537	6107	5683	5812	5752	5342	4679	4973	4839	500
600							4667	7014	6828	6182	6347	7140	6705	6780	6692	6322	5491	5866	5729	600
700							5079	7889	7603	6874	7055	8080	7653	7705	7589	7302	6294	6713	6591	700
800							5484	8639	8243	7469	7665	8892	8473	8565	8397	8234	7046	7481	7399	800
900							5889	9279	8786	7994	8190	9577	9188	9307	9092	9077	7714	8163	8141	900
1000							6292	9834	9283	8482	8662	10162	9830	9940	9704	9822	8304	8776	8826	1000
1200							7092		10223	9422	9567		10960	11070		11152	9349	9871	10026	1200
1400										10337	10467		11935	12115		12327		10856		1400
1600										11242			12830							1600
1800										12147										1800
2000																				2000

Stations

A. Anomalies of Specific Volume. $10^5 (\alpha - \alpha_{35,0,p})$

p d-bars	97	98	99	100	101	103	104	105	106	107	108	109	110	111	112	113	114	115	116	p d-bars
0	183	172	134	147	148	173	153	146	164	124	125	112	116	126	119	123	138	142	147	0
10	170	166	131	142	141	160	142	141	157	122	123	108	113	117	112	117	130	131	141	10
25	131	143	125	136	121	133	129	122	128	121	121	100	108	97	104	103	108	103	126	25
50	79	98	103	100	89	83	83	96	81	91	104	82	89	77	84	80	72	78	84	50
75	75	90	72	86	84	77	77	85	74	81	90	74	80	70	70	74	65	71	74	75
100	75	85	68	82	81	70	76	72	73	77	68	74	68	64	66	72	63	67	70	100
150		80		76	76	68	73	66	72	69	65	73	64	58	62	67	58	61		150
200		78		75	74		74	65	73	66	59	72		52	62	63	54	58		200
300		80		73	74			59	73	57				50	60	57	43	45		300
400		80		73	75			49	73	46					53	34	28	28		400
500		79		73	75			30	66	24					16	20	17	16		500
600		79		74	77			13	42	9						9	13			600
700		78		73	77				24	6						7	9			700
800		76		70	72				8							6	7			800
900		73		66	69				6								6			900
1000		68		61	64				6								7			1000
1200				54	56															1200
1400				49	49															1400
1600					44															1600
1800					41															1800
2000																				2000

B. Anomalies of Depth of Isobaric Surfaces. $10^4 (D - D_{35,0,p})$ dyn.metres

p d-bars	97	98	99	100	101	103	104	105	106	107	108	109	110	111	112	113	114	115	116	p d-bars
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	177	169	132	145	145	167	148	144	161	123	124	110	115	122	115	120	134	136	144	10
25	402	400	323	353	341	386	350	340	374	305	307	265	280	282	276	285	311	311	344	25
50	665	701	607	647	603	655	614	612	635	569	587	492	526	499	510	514	536	538	605	50
75	857	935	825	880	818	853	813	838	828	784	829	687	736	682	701	706	707	723	801	75
100	1043	1153	999	1089	1024	1036	1003	1035	1011	980	1026	871	920	848	870	887	867	894	981	100
150		1564		1484	1416	1381	1376	1378	1373	1345	1359	1238	1249	1152	1189	1234	1186	1213		150
200		1959		1862	1791		1743	1703	1736	1683	1669	1601		1426	1498	1556	1447	1511		200
300		2747		2602	2531			2321	2463	2298				1933	2105	2151	1932	2026		300
400		3544		3332	3274			2858	3191	2810					2670	2604	2284	2391		400
500		4339		4062	4019			3248	3883	3155					3015	2874	2507	2611		500
600		5129		4797	4776			3461	4421	3318						3019	2657			600
700		5914		5529	5544				4751	3393						3096	2764			700
800		6682		6239	6286				4911							3159	2839			800
900		7422		6917	6991				4981								2899			900
1000		8122		7552	7656				5041								2959			1000
1200				8697	8856															1200
1400				9717	9906															1400
1600					10831															1600
1800					11676															1800
2000																				2000

Table V. Current Measurements.

Stat. 18. 29.—30. April 1910. 35° 56′ N. 5° 43′ W.

Magnetic variation 15° W. — All *directions* are magnetic with the exception of those in column 6 (Mean direction).

The *current measurements* on April 29th were made from the *life-boat*, fastened between two grapnels (velocity and mean direction printed in *italics*.) The observations on April 30th were made from the *S/S "Michael Sars"*, anchored with one anchor (fore) and 660 m. of trawl-wire.

Notes on the *weather:* On April 30th a light breeze was blowing from S 70° W in the forenoon, from 12 to 12.30 slightly brisker without change in direction, afterward slackening to calm at about 1.30 p.m., at 2 p.m. a very gusty wind began blowing from N 60° E, veering to N 5° E at 3 p.m.

No.	Time: LMT	Time: GMT	Velocity cm/sec: Observed	Velocity cm/sec: Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation: Begin.	Middle	End
	29. April		**5 metres:**									
1[1])	16h 50m	17h 13m	*113*			41	2.0	590	No indication.			
2[1])	17 5	28	*124*			„	2.0	648	[1 N10E; 1 N10W; 1 N80W; 1 S10E; 1 S40E]			
3	„	„	*119*	*119*	*N62E*	31	2.0	642	4 N70E; 9 N80E			
4[1])	16	39	*123*			41	2.0	647	[2 S40E; 1 S30E; 1 S80W; 1 S30W; 1 N80W; 1 N70W; 1 N20W]			
5	36	59	*154*	*154*	*S28E*	30	2.0	788	1 S20W; 1 S10W; 3 S10E; 9 S20E			
6	45	18 8	*162*	*133*	*S68E*	„	2.0	818	1 S; 1 S30E; 3 S50E; 3 S60E; 3 N80E; 1 S20W			
	30. April		**9 metres:**									
7	1h 32m	1h 55m	48	47	N79W	31	4.0	515	8 N60W; 5 N70W		S58E	
8	2 21	2 47	44	44	S85W	„	2.0	235	1 N70W; 4 N80W; 1 W		S52E	
9	3 41	4 4	31	30	N63W	„	3.0	243	1 N30W; 4 N50W; 1 N60W		S22E	
10	4 3	26	20	20	N30W	„	3.0	158	1 N10W; 1 N20W		S10W	
11	10	33	27	26	N42E	„	3.0	209	4 N50E; 2 N70E	S57W		S72W
12	5 20	5 43	71	71	N72E	„	3.0	573	2 N70E; 11 E		N87W	
13	30	53	71	70	N72E	„	3.0	567	4 N80E; 8 E		N87W	
14	39	6 2	81	81	N74E	„	3.0	653	2 N80E; 10 E; 1 S80E			N74W
15	6 8	31	86	85	N77E	„	3.0	688	1 N80E; 9 E; 3 S80E		N71W	
16	29	52	96	95	S80E	„	3.0	769	8 S60E; 4 S70E; 1 S80E		N70W	
17	45	7 8	100	99	S87E	„	3.0	805	1 S50E; 1 S60E; 6 S70E; 4 S80E; 1 E		N62W	
18	7 4	27	97	96	N87E	„	3.0	780	2 S70E; 7 S80E		N89W	
19	26	49	105	102	N64E	„	3.0	842	2 N60E; 4 N70E; 4 N80E; 3 E; 2 S80E		N64W	
20	50	8 13	110	109	N48E	„	3.0	887	3 N50E; 3 N60E; 7 N70E		N75W	
21	8 11	34	111	109	N57E	„	3.0	895	1 N50E; 3 N60E; 2 N70E; 6 N80E; 1 E		N78W	
22	47	9 10	117	116	N32E	„	2.0	633	6 N40E; 5 N50E; 1 N70E		N79W	
23	9 13	36	101	100	N60E	„	2.0	542	1 N60E; 4 N70E; 8 N80E		N72W	
24	45	10 8	112	111	N48E	„	2.0	602	10 N60E; 2 N70E; 1 N80E		N60W	
25	10 21	44	94			30	2.0	480	No indication		N70W	
26	29	52	99			„	2.0	506	No indication		N73W	
27	„	„	97	97	N53E	31	2.0	523	2 N60E; 11 N70E		„	
28	38	11 1	102			30	2.0	522	[2 S20E; 5 S30E; 4 S40E; 3 S50E]		N69W	
29	45	8	94			„	2.0	479	No indication		N70W	
30	52	15	92	91	N73E	„	2.0	471	4 N80E; 8 E; 1 S80E		N72W	

[1]) Nos. 1, 2 and 4:—In these cases the magnetic needle of the Instrument Ekman no. 41 did not move freely; therefore the indications of direction are of no value.

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (Magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	30. April		**9 metres:**									
31	10h 52m	11h 15m	91	91	N59E	31	2.0	489	8 N70E; 5 N80E		N72W	
32	11 2	25	68	68	S87E	30	2.0	345	8 S70E; 2 S80E		N76W	
33	10	33	65	65	N79E	„	2.0	330	4 S80E; 5 E		N81W	
34	17	40	57	57	S86E	„	2.0	289	7 S70E; 1 S80E		N70W	
35	24	47	57	57	S86E	„	2.0	290	1 S60E; 6 S70E; 2 S80E		N76W	
36	36	59	51	50	N84E	„	2.1	273	1 S60E; 6 S80E; 1 N80E		N76W	
37	45	12 8	45	44	N89E	„	2.0	227	3 S70E: 4 S80E		N73W	
38	56	19	44	43	S76E	„	2.0	221	1 S50E; 4 S60E; 2 S70E		N73W	
39	12 3	26	47	47	N86E	„	2.0	241	1 S70E; 6 S80E		N71W	
40	11	34	55	55	S75E	„	2.0	278	8 S60E		N65W	
41	19	42	49	49	S74E	„	2.0	247	1 S50E; 7 S60E			
42	27	50	48	48	S75E	„	2.0	241	7 S60E		N62W	
43	13 44	14 7	36?	35?	S46E	41	3.0?	283	2 S10E; 3 S30E; 1 S50E; 1 S60E		N25W	
44	14 51	15 14	50	50	S53E	30	3.0	382	2 S30E; 10 S40E		N5W	
45	16 9	16 32	71	71	N82E	„	2.5	453	1 S70E; 7 S80E; 5 E		S70W	
	29. April		**20 metres:**									
46	17h 31m	17h 54m	*131*	*130*	*N23E*	31	1.9	667	3 N30E; 8 N40E; 1 N50E			
	29. April		**40 metres:**									
47	17h 49m	18h 12m	*148*	*147*	*N20E*	31	2.8	1113	8 N30E; 2 N40E; 2 N50E			
	30. April											
48	5h 39m	6h 2m	84	84	N82E	31	2.8	633	3 E; 9 S80E	N71W		N74W
49	6 38	7 1	97	97	N57E	„	2.8	730	11 N70E; 2 N80E		N65W	
50	7 36	59	99	98	N77E	„	2.8	745	1 N80E; 9 E; 4 S80E		N67W	
51[1]	8 2	8 25	95	95	N63E	„	2.8	715	4 N70E; 7 N80E; 2 E		N76W	
52[2]	10 0	10 23			N46E	„	4.8		1 N50E; 10 N60E; 2 N70E		N64W	
53	18	41	84	83	N67E	„	4.8	1078	1 N70E; 9 N80E; 4 E		N70W	
54	14 1	14 24	9	9	N13W	41	4.8	111	1 N10W; 2 N; 1 N20E	N23W		N28W
			70 metres:									
55	5h 58m	6h 21m	89	88	N52E	31	2.7	642	1 N50E; 3 N60E; 8 N70E; 1 N80E		N77E	
56	6 55	7 18	100	100	N84E	„	3.2	860	11 S80E; 1 E		N58W	
57	9 1	9 24	93	92	N68E	„	4.7	1167	9 N80E; 3 E		N73W	
58	10 43	11 6	38	37	S70E	„	4.7	470	1 S40E; 5 S50E; 6 S60E; 1 S70E		N69W	
59[3]	14 15	14 38	[70]	[68]	[N48W]	41	6.7	1217	[4 N20W; 4 N30W; 4 N40W; 2 N50W]		N12W	
60	16 21	16 44	85	82	N78E	30	3.7	802	2 S60E; 2 S70E; 1 S80E; 2 E; 7 N80E	N60W		N5E
			150 metres:									
61	6h 18m	6h 41m	37	37	N62W	31	2.5	243	2 N40W; 4 N50W		N73W	
62	7 15	7 38	32	32	N81W	„	2.5	210	2 N60W; 3 N70W		N66W	
63	9 30	9 53	34	33	S79W	„	6.5	578	5 N80W; 8 W		N64W	

[1]) No. 51:—Salpae were found on the propeller and wing of the Current-meter. The velocity measured is perhaps too low.

[2]) No. 52:—The great messenger did not reach the Current-meter so that the apparatus was hauled up without being arrested. The number of revolutions read off (2203) is therefore of no value. All shots had probably fallen into the compass-box before the instrument was hauled up so that the indication of direction is correct.

[3]) No. 59:—During the last two minutes of observation the ship swayed a great deal, due to a heavy wind blowing from N60E.

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	30. April		**175 metres:**									
64	11h 6m	11h 29m	44	44	S70W	31	7.0	824	7 S80W; 6 W	N76W		N81W
			200 metres:									
65[1])	1h 57m	2h 20m	246	245	S82W	31	9.2	6112	1 N70W; 7 N80W; 5 W	S59E		S60E
66[2])	15 11	15 34	[88]	[88]	S83W	30	[12.2]	2742	11 N80W; 3 W	N9W		N5W
			250 metres:									
67	8h 29m	8h 52m	19	19	N79W	31	4.2	208	3 N60W; 2 N70W		N78W	
68	11 30	11 53	63	63	S75W	"	9.2	1556	12 W			N76W
			320 metres:									
69[3])	12h 4m	12h 27m	12]			31	9.4	280	No indication	N73W	N71W	N65W

Stat. **19 C.** 2.—3. May 1910. Ca. 36° 8′ N. 4° 25′ W.

Magnetic Variation 15° W.—All *directions* are magnetic with the exception of those in Column 6 (Mean Direction).
The *current measurements* were made when the s/s "Michael Sars" was *trawling* at a fairly constant speed (37 revolutions in the engine).
Notes on the *weather*:—at the beginning of the experiments calm weather and smooth sea were experienced; at about 2h 30m a feeble breeze from N began blowing.

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	2. May	*3. May*	**5 metres:**									
70[4])	23h 50m	0h 8m	63	61	N75E	30	3.0	479	4 N80E; 9 E; 1 S50E		N87E	
	3. May											
71[4])	0h 35m	0h 53m	63	63	N74E	"	3.5	561	2 N80E; 12 E		S81E	
72	1 4	1 22	70	69	S84E	"	3.0	536	1 E; 2 S80E; 7 S70E; 3 S60E, 1 S50E	S76E		S75E
73	48	2 6	70	69	S87E	"	3.0	537	1 E; 3 S80E; 6 S70E; 3 S60E		S70E	
74	2 29	47	52	52	N89E	"	4.0	530	8 S80E; 5 S70E	S67E		S68E
75	3 14	3 32	47	46	S83E	"	3.0	355	1 S80E; 6 S70E; 3 S60E		S58E	
			20 metres:									
76[4])	0h 45m	1h 3m	45	45	S72E	"	2.9	334	6 S60E; 3 S50E	S78E		S80E
77	2 39	2 57	45	45	S68E	"	2.9	330	3 S60E; 6 S50E	S63E		S60E
			40 metres:									
78[4])	0h 55m	1h 13m	58	58	S62E	"	3.8	565	9 S50E; 4 S40E	S75E		S75E
79[4])	2 49	3 7	38	38	S45E	"	2.8	269	8 S30E	S60E		S58E
			80 metres:									
80[4])	1h 16m	1h 34m	19	19	S41W	"	5.7	265	1 S40W; 1 S50W; 5 S60W	S76E		S72E
81[4])	3 4	3 22	56	56	S85W	"	5.7	809	13 N80W	S65E		S60E

[1]) No. 65:—The line was strongly deflected towards W. when the Current-meter was lowered to greater depths than 50 metres. 274 metres of line were let out.

[2]) No. 66:—The line was strongly deflected (westwards) under the keel of the ship. The large messenger had possibly been held by the ship's side for 3.5 min. so that the duration of the measurement had been 15.7 min and the velocity 68 cm/sec (instead of 12.2 and 88 resp.) 274 m. of line were let out.

[3]) No. 69:—The apparatus had been in contact with the rocky bottom. The wing was bent, and the compass-box torn off; the propeller moved much more slowly than usual. The accident took place at the commencement of the observation, and the apparatus was free from the bottom shortly afterwards. The hands showing the number of revolutions had the right position in relation to each other but had probably moved only after the damage so that the actual velocity was much greater than that calculated.

[4]) Nos. 70, 71, 76, 78, 79, 80, 81:—The wire was a little defected forwards (towards E).

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Direction of Currents indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	3. May		**170 metres:**									
82[1])	1h 35m	1h 53m	68	68	N87W	30	6.5	1132	3 N80W; 10 N70W	S79E		S80E
			300 metres:									
83[2])	0h 9m	0h 27m	58	57	S86W	„	9.2	1351	13 N80W; 1N70W	S82E	E	N88E
84[3])	2 11	2 29	67	66	S86W	„	6.0	1023	12 N80W; 1 N70W	S66E		S65E
85[3,4])	3 32	3 50	64	[62]	[N59W]	„	6.5	1064	[1 N80W; 5 N50W; 3 N40W; 2 N20W]	S58E	S60E	S57E

Stat. 47. 30. May 1910. Ca. 28° 52′ N. 22° 50′ W.

Magnetic Variation 19° W.—All *directions* are magnetic with the exception of those in column 6 (Mean direction).

The *current measurements* were made from the s/s "Michael Sars" *when hauling the trawl.* The ship was moving slowly at a fairly constant speed till about 17h 30m when the speed was somewhat reduced. This reduced speed was afterwards kept nearly constant during the later part of the observations.

Notes on the *weather:*—during the experiments a feeble breeze was blowing from NE.—Moderate swell.

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Direction of Currents indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	30. May		**9 metres:**									
86	16h 56m	18h 28m	40	39	N 3W	30	3.0	304	N; 4 N10E; 3 N30E		S10E	
87	17 34	19 6	33	32	N34W	„	3.0	251	2 N; 2 N10W; 1 N20W; 1 N50W		S29E	
88	18 2	34	34	33	N33W	„	3.0	255	2 N; 2 N10W; 1 N20W; 2 N30W		S32E	
89	31	20 3	29	28	N83W	„	3.	216	1 N40W; 1 N60W; 2 N70W; 1 N80W		S62E	
			90 metres:									
90[5])	17h 7m	18h 39m	29	29	N38W	„	3.7	275	2 N10W; 5 N20W; 1 N30W		S11E	
			175 metres:									
91[6])	17h 23m	18h 55m	41	41	N39W	„	4.9	ca.510	1 N10W; 11 N20W; 1 N30W		S11E	
			300 metres:									
92[7])	18h 22m	19h 54m	47	47	N46W	„	3.9	469	3 N20W; 9 N30W		S31E	

[1]) No. 82:—The wire was a little deflected towards W.

[2]) Nos. 83, 85:—The wire was deflected about 30° towards W. 366 m. of line were let out.

[3]) No. 84:—The wire was deflected astern and a little away from the ship (towards W).

[4]) No. 85:—The apparatus was tipped when taken in so that the shots were to some extent scattered, and the indications of direction are consequently unreliable.

[5]) No. 90:—The line was a little deflected.

[6]) No. 91:—The line was deflected (15—20°); 183 m. of line were let out.

[7]) No. 92:—The line was strongly deflected (up to 40—45°); 366 m. of line were let out.

Stat. **49 C.** 1.—2. June 1910. 29° 2′ N. 25° 30′ W.

Magnetic variation 19° W.—All *directions* are magnetic with the exception of those in column 6 (Mean direction).
The *current measurements* were made from the s/s "Michael Sars" when the ship was *drifting with a big plankton-net* (3 m. diameter), *suspended by the trawl-wire at a depth of 1000 metres.* The propeller of the ship was not moved.
Notes on the *weather:*—Before midnight (1. June) a feeble breeze was blowing from N. Afterwards calm.

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	1. June		**9 metres:**									
93	22h 11m	23h 53m	18	18	N49W	30	3.0	138	1 N20W; 1 N30W; 1 N40W		S66W	
94	»	»	18			41	3.0	138	No indication.		»	
	1. June	*2. June*										
95	22h 26m	0h 8m	19			»	3.0	145	No indication.		S65W	
96	36	18	19	18	N44W	»	3.0	142	1 N; 2 N30W; 1 N40W		S63W	
97	43	25	19	19	N52W	»	3.0	145	1 N20W; 1 N30W; 2 N40W		S64W	
98	50	32	19	19	N41W	»	3.0	145	1 N10W; 1 N20W; 2 N30W		S61W	
99	58	40	18	18	N41W	»	3.0	140	4 N20W; 1 N30W		S62W	
100	23 4	46	19	19	N45W	»	6.0	300	4 N20W; 5 N30W		S67W	
101	13	55	18	18	N49W	»	3.0	140	1 N20W; 2 N30W; 1 N40W		S69W	
102	19	1 1	20	19	N31W	»	4.0	200	2 N; 1 N10W; 3 N20W	S68W		N85W
103	27	9	19	19	N41W	»	3.0	145	1 N; 1 N20W; 3 N30W	N82W		N72W
104	38	20	15	15	N26W	»	3.0	117	1 N; 2 N10W	N82W		S88W
105	45	27	15	14	N36W	»	3.5	130	2 N10W; 1 N20W; 1 N30W		W	
106	52	34	15	15	N34W	»	4.0	152	3 N10W; 1 N30W			W
107	58	40	14	14	N34W	»	3.0	105	2 N10W; 2 N20W			S79W
	2. June											
108[1]	0h 5m	1h 47m	14	13	N29W	»	3.0?	103	1 N; 1 N10W; 1 N20W		S73W	
109	12	54	13	13	N22W	»	3.0	100	2 N; 1 N10W		S88W	
110	19	2 1	11	11	N39W	»	4.0	109	3 N20W		S76W	
111	30	12	12	12	N40W	»	11.5	360	2 N10W; 5 N20W; 3 N30W	S74W		S75W
112	42	24	13	12	N44W	»	3.0	95	2 N20W; 2 N30W		S74W	
113	48	30	11	11	N44W	»	3.0	85	1 N20W; 1 N30W		S59W	
114	54	36	11	11	N44W	»	4.0	116	3 N20W; 1 N40W		S74W	
115	1 1	43	10	10	N39W	»	3.0	76	1 N10W; 1 N30W		S75W	
116	7	49	12	12	N46W	»	3.5	102	1 N20W; 2 N30W	S73W		S51W
117	14	56	11	11	N59W	»	3.0	82	1 N30W; 1 N50W		S45W	
118	20	3 2	11	10	N62W	»	3.0	80	1 N30W; 1 N40W; 1 N60W		S48W	
119	28	10	10	10	N74W	»	3.0	77	1 N50W; 1 N60W		S37W	
120	33	15	11	11	N74W	»	4.0	115	1 N40W; 1 N50W; 1 N60W; 1 N70W		S34W	
121	48	30	12	12	N69W	30	3.5	101	1 N40W; 1 N50W; 1 N60W	S54W		S50W
122	»	»	12	12	N66W	41	3.5	102	1 N40W; 2 N50W	»		»
123	55	37	11	11	N66W	»	3.0	86	2 N40W; 1 N60W		S53W	
124	2 3	45	12	12	N62W	»	3.5	105	2 N40W; 1 N50W	S52W		S57W
125	10	52	13	13	N56W	»	3.0	95	1 N30W; 2 N40W	S60W		S61W
126	21	4 3	12	12	N44W	»	12.3	361	5 N20W; 5 N30W	S63W		S72W
127	36	18	13	13	N29W	»	3.5	116	4 N10W	S69W		S67W
128	43	25	9	9	N54W	»	3.5	80	1 N30W; 1 N40W			S58W

[1]) No. 108:—The duration of the observation had possibly been 4 min. instead of 3 min. (velocity 10 cm/sec instead of 14).

No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	2. June		**9 metres:**									
129	2h 51m	4h 33m	9	9	N44W	41	3.0	68	1 N20W; 1 N30W	S65W		
130	57	39	11	10	N39W	„	3.0	80	1 N10W; 1 N20W; 1 N30W	S72W		
131	3 2	44	10	10	N49W	„	3.0	75	1 N20W; 1 N40W		S84W	
132	9	51	9	9	N44W	„	3.0	67	1 N20W; 1 N30W	S68W		
133	17	59	13	13	N44W	„	4.0	130	2 N20W; 2 N30W		S70W	
134	25	5 7	9	9	N66W	„	4.0	89	1 N40W; 2 N50W	S65W		S64W
135	33	15	8	8	N49W	„	3.0	60	1 N30W	S75W		S80W
136	39	21	8	8	N64W	„	3.0	60	1 N40W; 1 N50W			S74W
137	46	28	9	8	N49W	„	5.5	117	2 N20W; 2 N40W		S79W	
138	58	40	6	6	N30W	„	10.0	157	1 N10E; 1 N10W; 1 N20W; 1N30W	S82W		S82W
139	4 12	51	5	4	N56W	„	8.0	87	1 N20W; 1 N40W; 1 N50W			N82W
140	25	6 7	5	5	N55W	„	12.0	153	2 N30W; 3 N40W	N89W		S82W
141	40	22	4	4	N19W	„	8.5	72	2 N	N88W		N88W
142	54	36	6	5	N31E	„	13.0	174	2 N40E; 2 N50E; 1 N70E	N78W		N77W
143	5 9	51	6	6	N44E	„	7.0	96	2 N60E; 1 N70E			N70W
144	20	7 2	2	2	N41E	„	7.0	31	1 N60E	N74W		N73W
145	34	16	12	12	N41W	„	13.5	418	1 N; 1 N10W; 5 N20W; 3 N30W; 1 N40W	N84W		S80W
146	5 51	33	12	11	N33W	„	10.0	293	1 N; 3 N10W; 4 N20W	N81W		N62W
147	„	„	11	11	N22W	30	10.0	279	4 N10W; 2 N; 2 N10E	„		„
			46 metres:									
148	2h 23m	4h 5m	11	10	N48W	30	11.0	283	2 N10W; 1 N20W; 2 N30W; 4 N40W	S63W		S72W
	1. June	*2. June*	**91 metres:**									
149	22h 27m	0h 9m	3	3	N69W	30	4.2	26	1 N50W		S65W	
	2. June											
150	2h 2m	3h 44m	5	5	S14W	„	9.3	110	2 S30W; 1 S40W	S49W	S52W	S57W
			183 metres:									
151	2h 43m	4h 25m	6	6	S24W	30	7.8	103	2 S40W; 1 S50W	S67W		S58W
	1. June		**274 metres:**									
152	22h 46m	0h 28m	5	5	N21W	30	7.2	82	2 S40W	S64W		S61W
	2. June											
153	3h 5m	4h 47m	13	13	S70W	„	9.7	313	8 W; 1 S80W	S79W	S84W	S68W
			457 metres:									
154	0h 39m	2h 21m	4	3	N89W	30	10.7	85	1 N50W; 1 N70W; 1 W	S75W		S74W
155	3 32	5 14	13	13	S85W	„	8.7	277	4 N70W; 5 N80W	S64W	S75W	S80W
			914 metres:									
156	1h 9m	2h 51m	7	7	N12W	30	12.3	227	2 N; 4 N10E	S51W		S45W
157[1]	4 11	5 53	7	7	N52W	„	16.7?	274	1 N20W; 4 N30W; 3 N40W	S82W	N82W	N89W
	1. June		**1829 metres:**									
158	23h 42m	0h 24m	4	4	N14W	30	16.5	125	3 N; 1 N20E	N82W	S88W	W
	2. June											
159	5h 11m	6h 53m	10	10	N58W	„	15.5	373	2 N30W; 8 N40W; 1 N50W	N77W	N70W	N74W

[1]) No. 157:—The duration of the observation had possibly been 15.7 min. instead of 16.7 min.

Stat. **58.** 12. June 1910. 37° 37′ N. 29° 25′ W.

Magnetic variation 23° W.—All *directions* are magnetic with the exception of those in column 6 (Mean direction).

The *current measurements* were made from the s/s "Michael Sars", *anchored (fore) with the trawl-wire.* The ship had been trawling with 3200 m. of wire out when the trawl (or wire) fastened to the bottom. The wire was fixed fore. When the current measurements were finished the wire was hauled in but broke so that only 1750 metres were secured. The ship had in all probability been moored with this length of the wire during the whole time.

Notes on the *weather:*—At the beginning a very feeble, but slowly increasing breeze was blowing (from SW). The following observations were made with the anemometer:—at 2h 40m velocity 3.6 m/sec, direction S60°W; at 5h 30m 4.7 m/sec, S40°W; at 11h 30m 3.7 m/sec, S45°W.

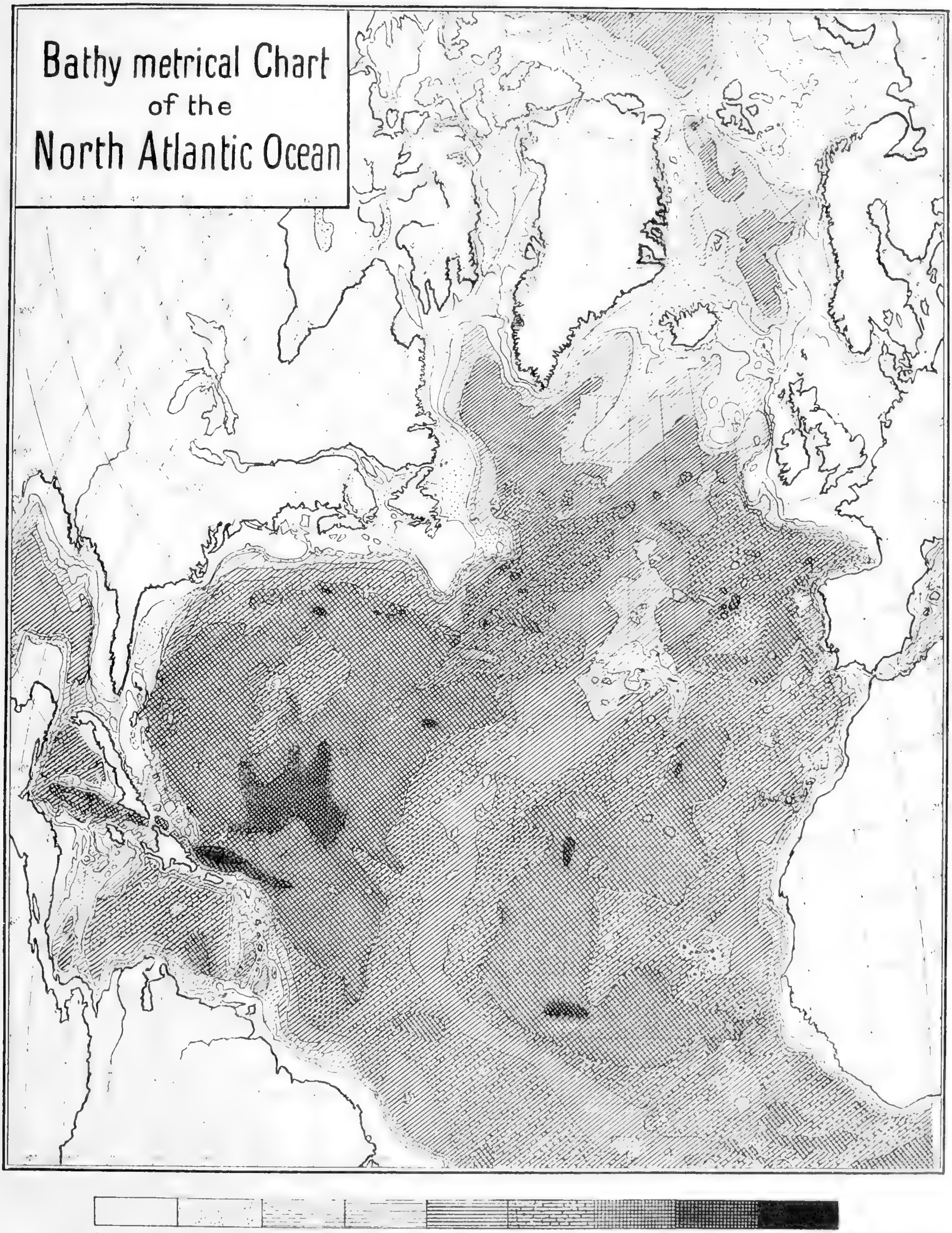
No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	12. June		**9 metres:**									
160	1h 4m	3h 2m	23	23	N 5E	30	5	291	2 N20E; 7 N30E	S52W		
161	"	"	24	24	N 4E	41	5	309	1 N10E; 3 N20E; 4 N30E; 1 N50E	S52W		
162	18	16	27	26	N27E	"	4.5	315	4 N40E; 2 N50E; 1 N60E; 1 N80E	S56W		S58W
163	32	30	34	32	N56E	"	7	618	1 N30E; 1 N60E; 4 N70E; 1 N80E; 2 E; 2 S80E; 1 S60E	S65W		S60W
164	51	49	26	24	N33E	"	10.5	696	2 N30E; 2 N40E; 4 N50E; 2 N60E; 2 N70E; 1 N80E; 1 S80E	S65W		S59W
165	2 9	4 7	26	25	N23E	"	6	403	3 N30E; 4 N40E; 1 N50E; 1 N60E; 1 N70E; 1 N80E	S61W		
166	23	21	27	26	N30E	"	9.5	653	3 N40E; 4 N50E; 3 N60E; 2 N70E	S69W		S68W
167	41	39	32	29	N42E	"	10	816	1 N30E; 3 N40E; 4 N60E; 1 N70E; 2 N80E; 2 S70E	S72W		S80W
168	3 3	5 1	32	30	N66E	"	15	1260	1 N50E; 3 N70E; 1 N80E; 2 E; 2 S80E; 1 S70E; 2 S60E	S81W		S81W
169[1]	24	22	28	27	N51E	"	12.5?	896	2 N50E; 1 N60E; 3 N70E; 2 N80E; 2 E; 1 S80E			S81W
170	41	39	27	26	N55E	"	6	412	1 N60E; 5 N70E; 2 N80E; 2 E; 1 S70E		S84W	
171	53	51	25	25	N71E	"	6	390	1 N80E; 3 E; 4 S80E		S86W	
172	4 20	6 18	26	26	N89E	30	7	463	5 S60E; 6 S70E; 2 S80E		N80W	
173	"	"	26	26	E	41	7	474	1 S50E; 3 S60E; 5 S70E; 2 S80E	W		N80W
174	37	35	31	31	S73E	"	7	559	3 S40E; 5 S50E; 3 S60E		N75W	
175	51	49	36	36	S61E	"	6	563	4 S30E; 5 S40E; 1 S60E		N62W	
176	5 5	7 3	38	38	S52E	"	10.5	1030	3 S20E; 4 S30E; 2 S40E	N59E		N52W
177	20	18	38	38	S45E	"	5	498	1 S10E; 5 S20E; 3 S30E			N56W
178	32	30	32	31	S47E	"	9	747	1 S; 5 S20E; 3 S40E		N64W	
179	46	44	32	32	S43E	"	7.5	625	2 S10E; 5 S20E; 2 S30E		N65W	
180	6 0	58	37	37	S46E	"	9	872	1 S; 1 S10E; 6 S20E; 5 S30E; 1 S40E	N60W		N64W
181	16	8 14	30	30	S50E	"	8	620	1 S10E; 5 S20E; 5 S30E; 3 S40E		N60W	
182	30	28	27	27	S42E	"	8	557	4 S10E; 5 S20E; 5 S30E		N62W	
183	47	24	24	23	S20E	"	12	728	2 S20W; 4 S10W; 5 S; 2 S10E; 1 S20E	N60W		N66W
184	7 5	9 3	26	25	S11W	"	10.5	697	1 S10W; 4 S20W; 4 S30W; 1 S40W; 3 S50W; 1 S80W	N43W		N48W
185	19	17	26	26	S6W	"	4	264	2 S20W; 4 S30W; 1 S40W	N49W		N54W
186	38	36	24	24	S2E	30	9	535	1 S10W; 11 S20W; 2 S30W	N42W		N48W
187	"	"	24	24	S6W	41	9	565	1 S10W; 5 S20W; 5 S30W; 2 S40W; 1 S60W	N42W		N48W
188	58	56	25	25	S6E	"	6.5	424	1 S; 3 S10W; 6 S20W; 1 S40W	N52W		N57W
189	8 26	10 24	22	22	S9E	"	3	170	4 S10W; 1 S30W		N70W	
190	34	32	22	22	S1E	"	3.5	200	1 S10W; 3 S20W; 2 S30W		N69W	
191	45	43	21	21	S19W	"	3	164	1 S30W; 3 S40W; 1 S60W		N52W	
192	9 6	11 4	25	24	S13W	"	3	190	3 S30W; 1 S40W; 1 S50W		N58W	

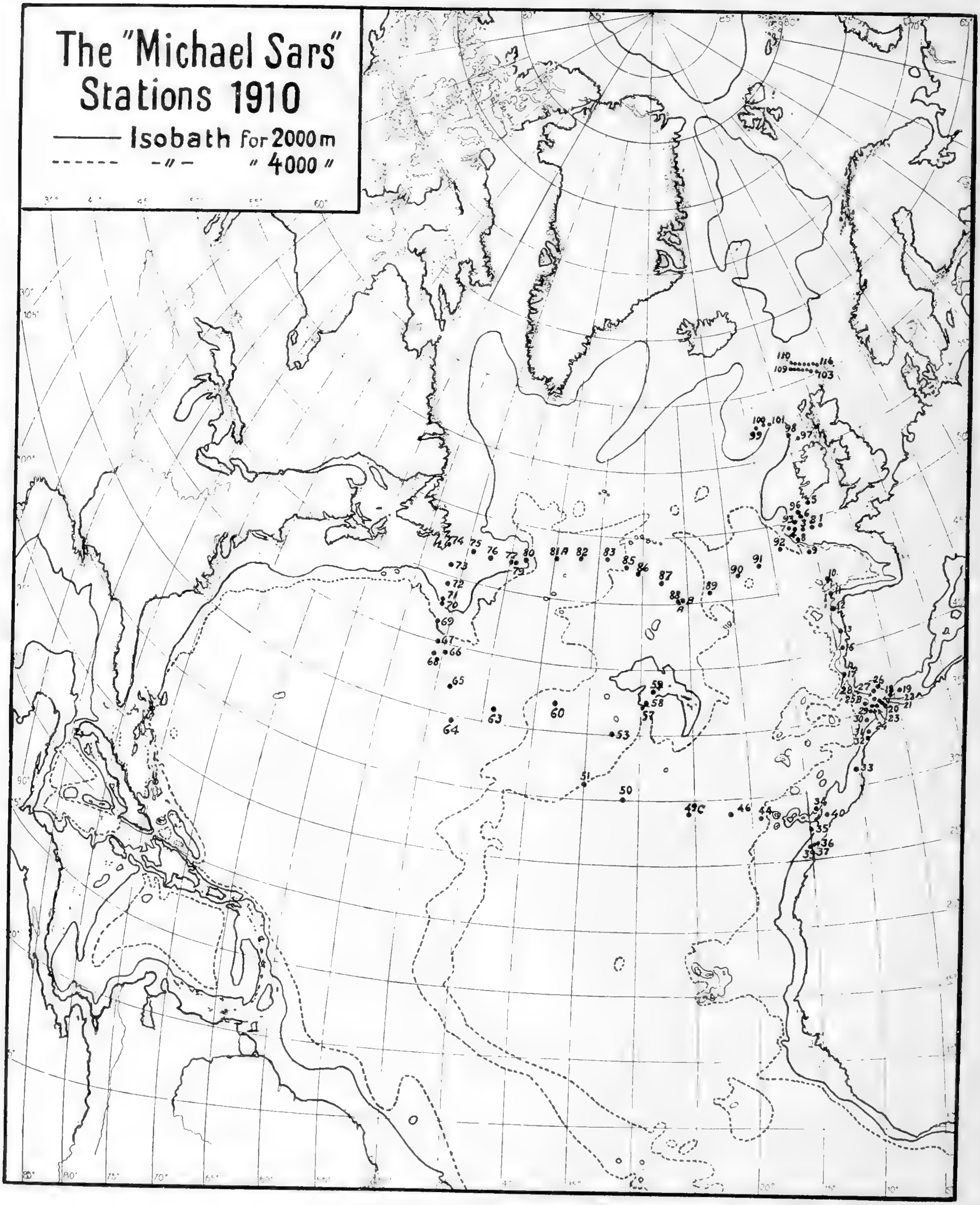
[1]) No. 169:—The duration of the observation had possibly been 13.5 min instead of 12.5 min.

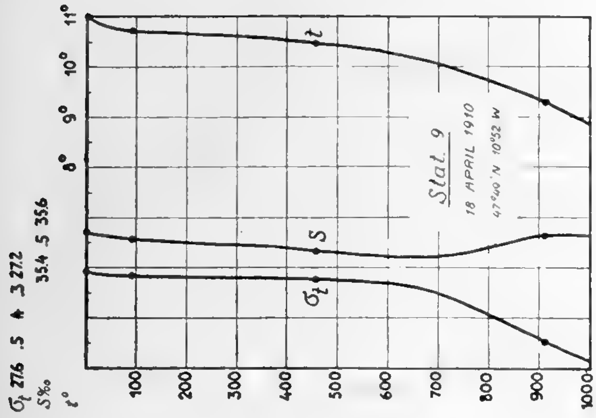
No.	Time LMT	Time GMT	Velocity cm/sec Observed	Velocity cm/sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	12. June		**9 metres:**									
193	9h 14m	11h 12m	24	24	S17W	41	3	189	2 S30W; 2 S40W; 2 S50W		N51W	
194	28	26	18	18	S 3E	„	3	136	1 S10W; 2 S20W; 1 S30W		N72W	
195	36	34	11	11	S13E	„	3	80	1 S10W		N88W	
196	45	43	23	22	S51W	„	3	176	2 S60W; 1 S70W; 1 S80W; 1 N80W		N73W	
197	52	50	22	21	S62W	„	3	169	1 S60W; 1 S80W; 3 W; 1 N80W		N40W	
198	59	57	21	21	S54W	„	3	162	2 S70W; 1 S80W; 1 W		N41W	
199	10 6	12 4	6	6	S48W	„	3	46	1 S20E; 1 S30E		N87W	
200	14	12	3	3	S83E	„	3	18	1 S60E		S73W	
201	20	18	2			„	3	15	No indication.		S76W	
202	27	25	14	14	S59W	„	5	175	2 S70W; 2 S80W; 1 W; 1 N80W		S72W	
203	37	35	14	14	S51W	„	5	180	1 S60W; 2 S70W; 1 S80W; 1 W		S82W	
204	47	45	13	12	N86W	„	5	169	1 S50W; 2 N30W		S83W	
205	54	52	15	15	S81W	„	5	194	1 N60W; 1 N70W; 1 S80W		S68W	
206	11 12	13 10	25	24	S70W	„	5	324	2 S70W; 2 S80W; 1 W; 2 N80W; 2 N70W; 1 N60W		N63W	
207	21	19	20	20	N 6E	„	5	261	1 N10E; 6 N30E; 1 N40E		S50W	
208	30	28	17	16	N40W	„	5	210	2 N20W; 5 N30W		S45W	
209	39	37	11	11	N58W	„	5	140	2 N30W; 2 N40W		S53W	
210	46	44	10	10	N68W	„	5	120	2 N40W; 2 N50W		S53W	
211	55	53	17	17	N58W	„	5	214	3 N30W; 3 N40W		S43W	
212	12 3	14 1	15	15	N60W	„	5	190	1 N20W; 1 N30W; 3 N40W; 1 N50W		S52W	
213	11	9	12	12	N58W	„	5	157	2 N30W; 2 N40W		S53W	
214	19	17	21	20	N46W	„	5	274	2 N; 4 N20W; 1 N40W; 1N60W		S47W	
215	28	26	8	8	N50W	„	5	100	1 N20W; 2 N30W		S52W	
216	39	37	12	12	N29W	„	12	374	1 N20E; 1 N10E; 4 N; 2 N10W; 1 N20W; 2 N30W	S54W		S51W
217	54	52	9	9	N13W	7	5	66	1 N10E		S51W	
218	13 5	15 3	6	6	N 3W	„	5	43	1 N20E		S56W	
219	„	„	6	6	N 7E	41	5	70	1 N20E; 1 N40E		S56W	
220	15	13	7	7	N33W	„	5	90	3 N10W		S62W	
221	24	22	8	8	N36W	„	5	96	2 N10W; 1 N20W		S59W	
222	33	31	1?			„	5	4	No indication.		S64W	
223	44	42	5	5	S33E	„	10	125	1 S20W; 1 S20E; 1 S30E		S68W	
224	57	55	6	5	N52E	„	7	96	1 S70E; 1 S80E; 1 N80E; 1 N10E		S66W	
225	14 10	16 8	15	15	N59E	„	7	270	2 S80E; 2 E; 2 N80E; 1 N70E; 1 N50E		S66W	
226	21	19	11	11	N71E	„	5	140	1 S70E; 2 S80E; 1 E; 1 N70E		S69W	
227	30	28	14	14	N51E	„	5.5	195	1 N60E; 2 N70E; 1 N80E; 1 E		S67W	
228	40	38	12	12	N51E	„	5	155	1 N60E; 1 N70E; 3 N80E		S65W	
229	47	45	13	13	N47E	„	5	165	2 N60E; 1 N70E; 2 N80E		S63W	
230	„	„	13	12	N42E	7	5	94	1 N50E; 1 N80E		S63W	
			46 metres:									
231	1h 23m	3h 21m	15	15	N33E	30	8.3	307	5 N50E; 3 N60E; 1 N70E	S58W		S65W
232	4 41	6 39	21	21	S41E	„	12.5	648	3 S10E; 11 S20E	N75W		N62W
233	8 1	9 59	22	22	S31W	„	11.0	603	9 S50W; 5 S60W			
234	11 18	13 16	26	23	N31W	„	9.8	666	1 N60W; 1 N40W; 1 N20W; 1 N10W; 6 N; 3 N10E			

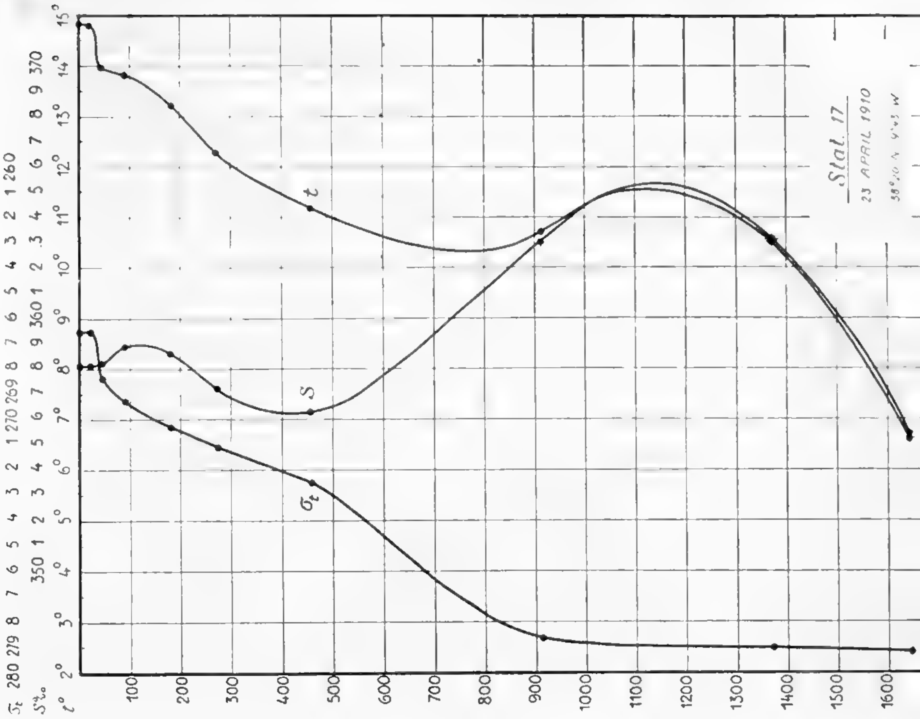
No.	Time LMT	Time GMT	Velocity cm sec Observed	Velocity cm sec Reduced	Mean Direction to (true)	Instrument Ekman No.	Duration of Observation (min.)	Number of Revolutions	Single Directions of Current indicated by the Ekman Current-Meter (magnetic)	Ship's Direction (magnetic) at Observation Begin.	Middle	End
	12. June		**91 metres:**									
235	1h 43m	3h 41m	14	14	N17W	30	9.9	350	5 N; 3 N10E; 1 N20E	S63W		S61W
236	5 6	7 4	13	12	S65E	"	14.0	430	1 S20E; 1 S30E; 5 S40E; 5 S50E	N59W		N52W
237	8 21	10 19	14	14	S64W	"	12.0	422	1 S70W; 6 S80W; 3 W; N80W; 1 N60W		N59W	
238	11 37	13 35	6	6	N40W	"	9.7	138	1 N10W; 2 N20W			
			183 metres:									
239	2h 11m	4h 9m	13	13	N63E	30	16.0	531	1 N70E; 5 N80E; 9 E; 1 S80E	S61W		S69W
240[1]	5 30	7 28	17	17	S39E	"	12.0	501	8 S10E; 4 S20E; 2 S30E	N56W		N64W
241	8 57	10 55	21	21	S22W	"	36.0	1912	6 S40W; 7 S50W			
242	12 17	14 15	15	15	N74W	"	10.0	383	1 N30W; 1 N40W; 6 N50W; 4 N60W			
			274 metres:									
243	11h 56m	13h 54m	12	12	N52W	30	11.8	348	3 N20W; 5 N30W; 2 N40W			
			320 metres:									
244	6h 0m	7h 58m	13	13	S59E	30	16.8	545	6 S30E; 8 S40E	N60W		N64W
245	9 36	11 34	11	11	S43E	"	11.2	307	1 S10W; 2 S; 1 S20E; 1 S30E; 3 S40E			
			457 metres:									
246	2h 48m	4h 46m	9	9	S84W	30	18.2	385	3 N60W; 4 N70W; 1 N80W; 1 W; 1 S80W	S72W	S80W	S81W
247[1]	6 38	8 36	9	9	N53E	"	13.0	266	3 N70E; 4 N80E	N62W		N60W
248	10 7	12 5	11		S76E	"	13.3	351	1 S70W; 1 S10W; 1 S40E; 1 S60E; 1 S70E; 1 S80E; 4 E			
249	13 30	15 28	4	3	S77W	7	21.7	97	1 N50W; 1 S70W			
			732 metres:									
250	3h 40m	5h 38m	17	17	S 2W	30	25.6	1068	3 S10W; 3 S20W; 8 S30W; 1 S40W	S81W	S84W	S86W
251	7 13	9 11	9	9	W	"	12.6	287	2 N50W; 2 N60W; 2 N80W; 1 W; (1 S)	N48W		N49W
252	10 50	12 48	5	5	N22E	"	12.3	143	(1 N60W); 2 N40E; 2 N50E			
253	14 17	16 15	6	6	S50E	"	20.3	293	1 S10W; 2 S20E; 2 S40E; 1 S50E			

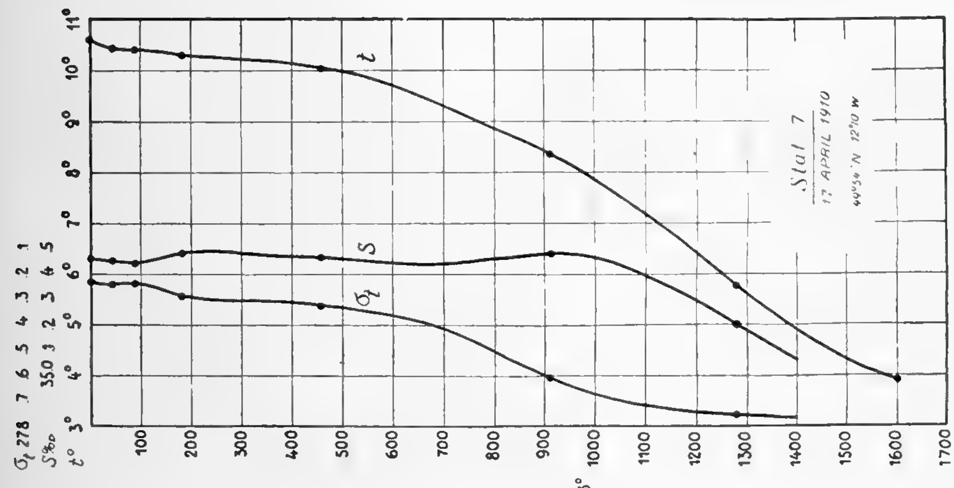
[1]) Nos. 240 and 247: The line was a little deflected (under the ship).

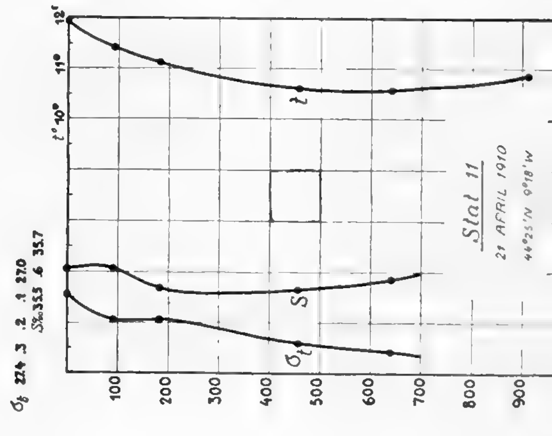

Bathy metrical Chart
of the
North Atlantic Ocean
0
200
1000
2000
3000
4000
5000
6000
7000 metres

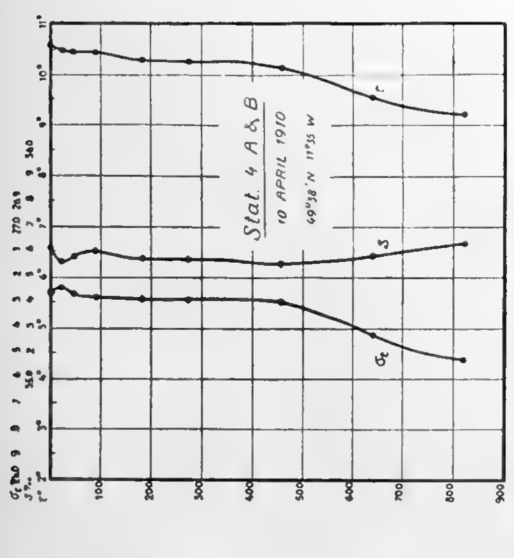

The "Michael Sars" Stations 1910
Isobath for 2000 m
" " 4000 "

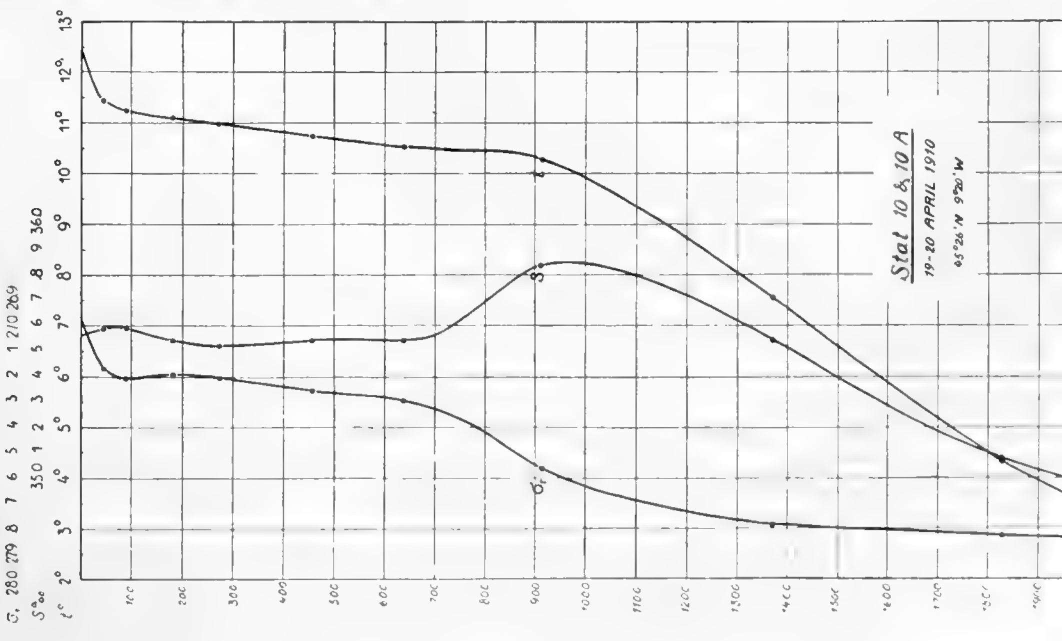

Stat. 9
18 APRIL 1910
47°40'N 10°52 W

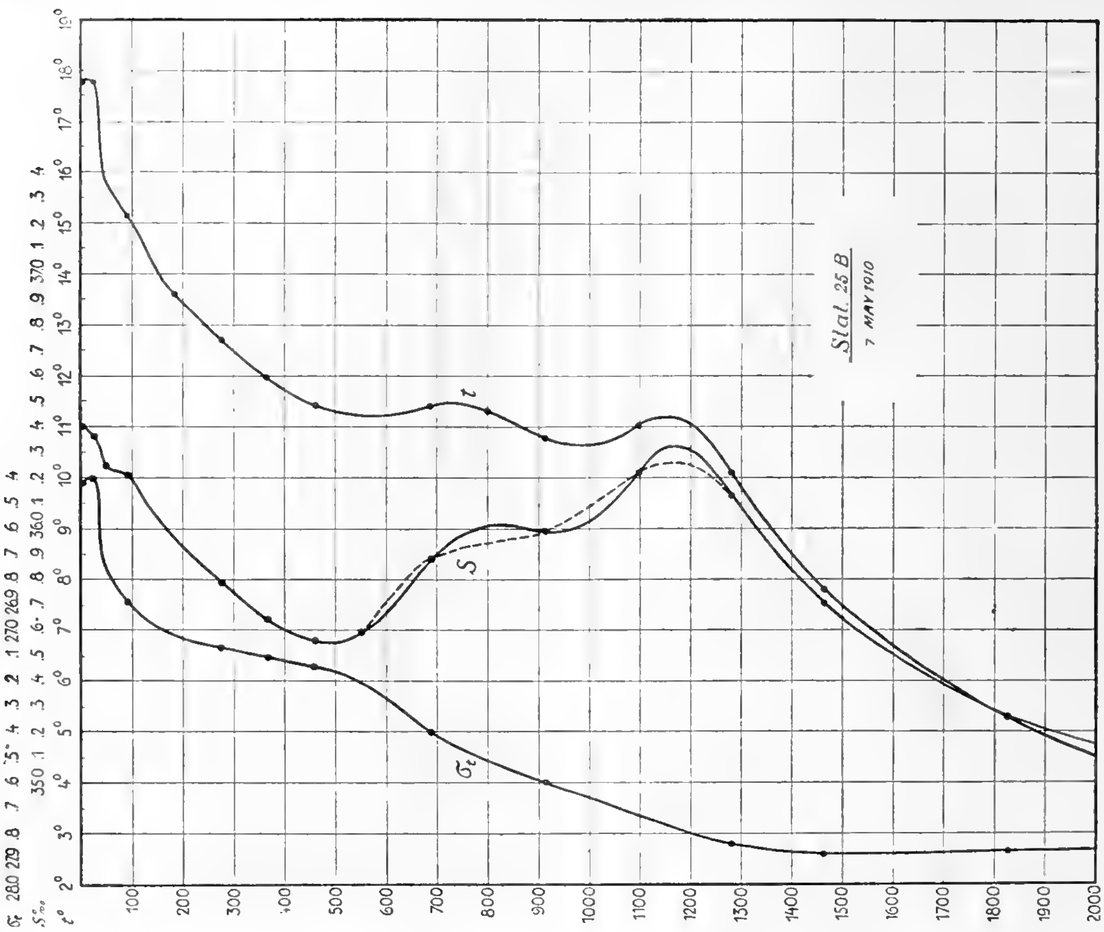

Stat. 17
23 APRIL 1910

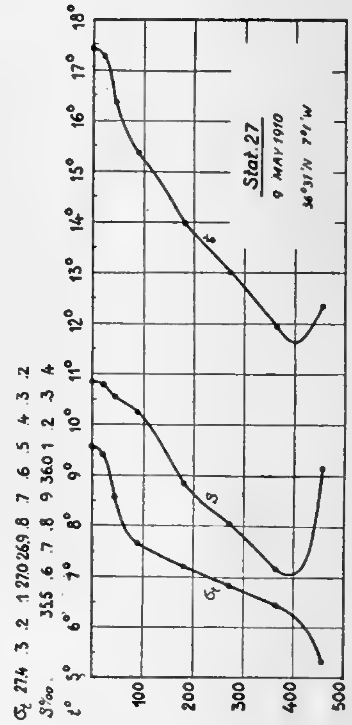

Stat 7
17 APRIL 1910
46°54'N 12°10 W

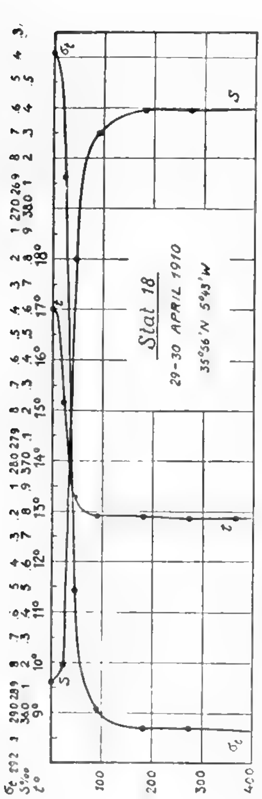

Stat 11
21 APRIL 1910
44°25'N 9°18'W

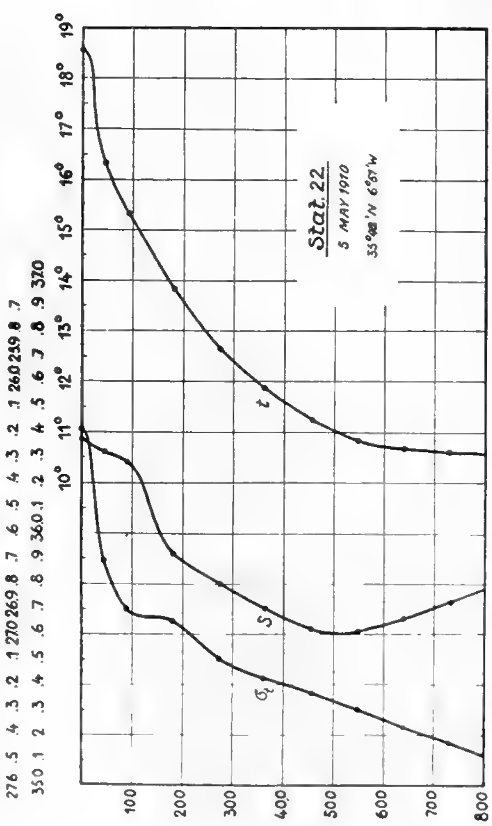

Stat. 4 A & B
10 APRIL 1910
49°38'N 11°35 W

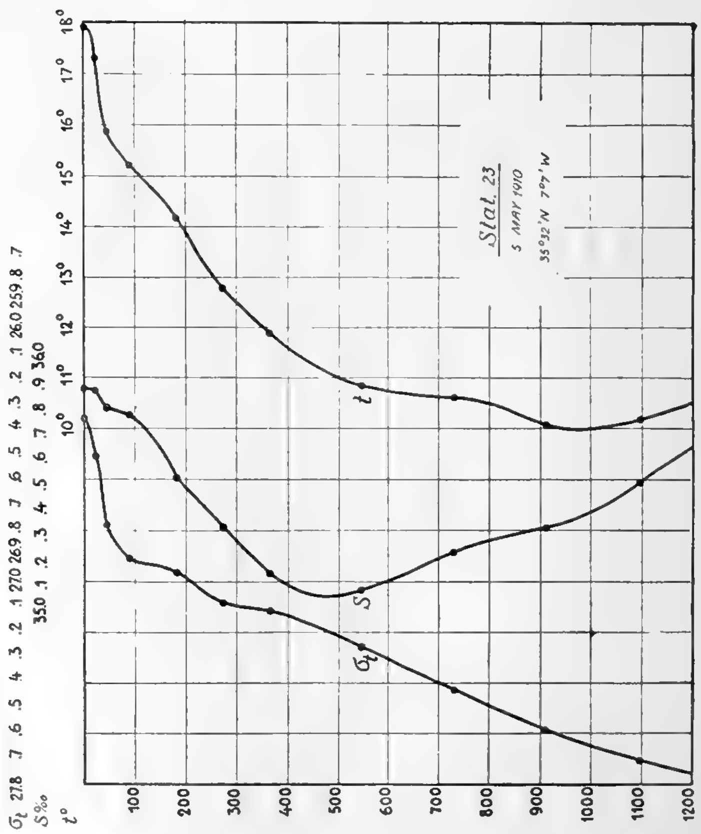

Stat 10 & 10 A
19-20 APRIL 1910
45°26'N 9°20'W

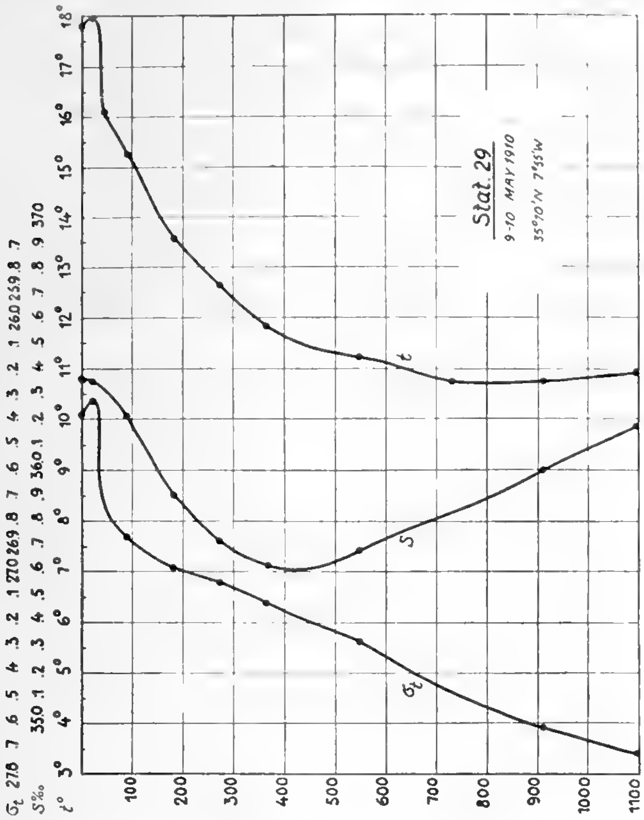

Stat. 25 B
7 MAY 1910
t
S
σ_t

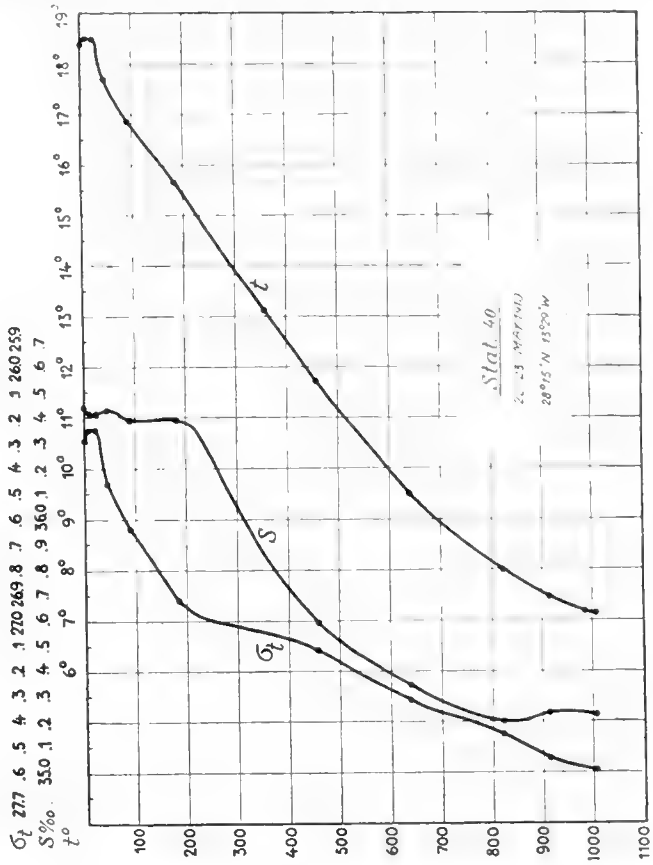

Stat. 27
9 MAY 1910
t
S
σ_t

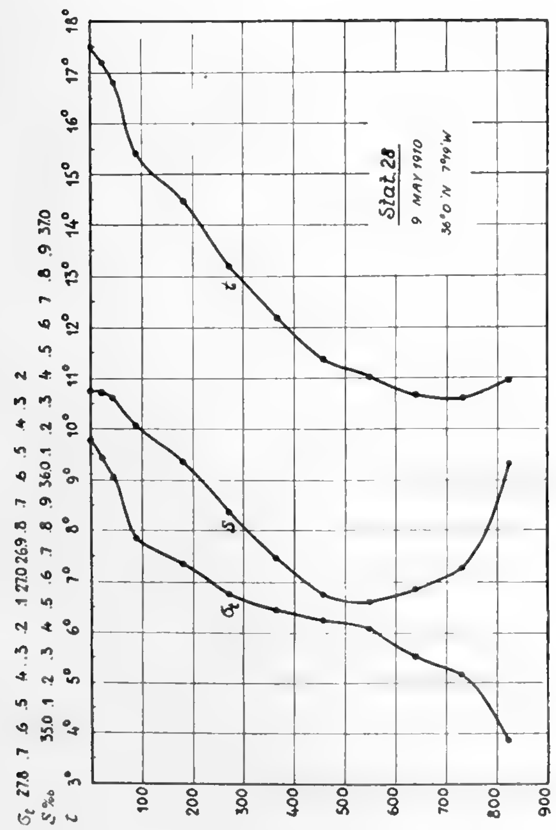

Stat 18
29-30 APRIL 1910
t
S
σ_t

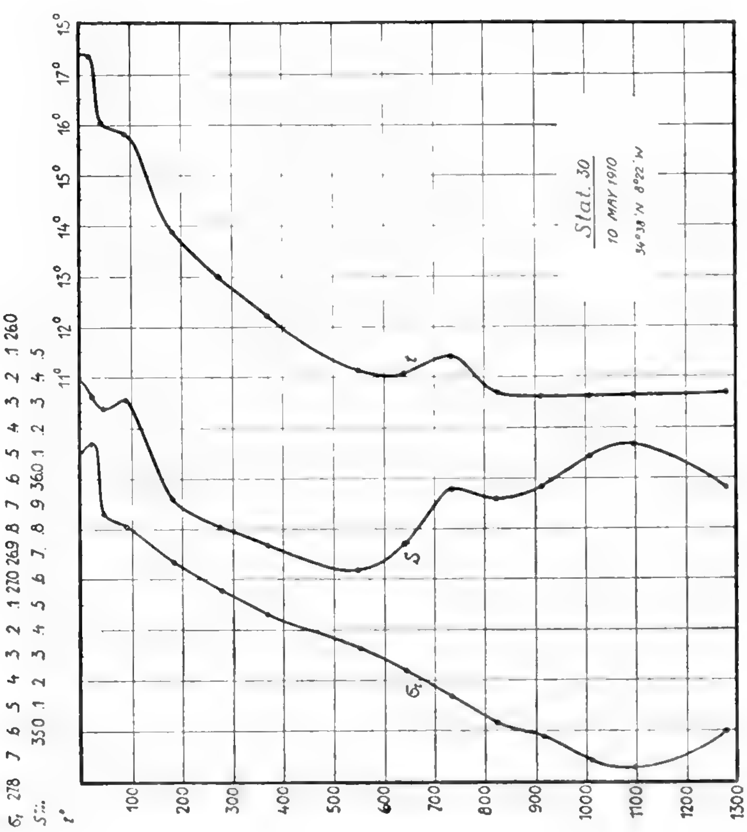

Stat. 22
5 MAY 1910
t
S
σ_t

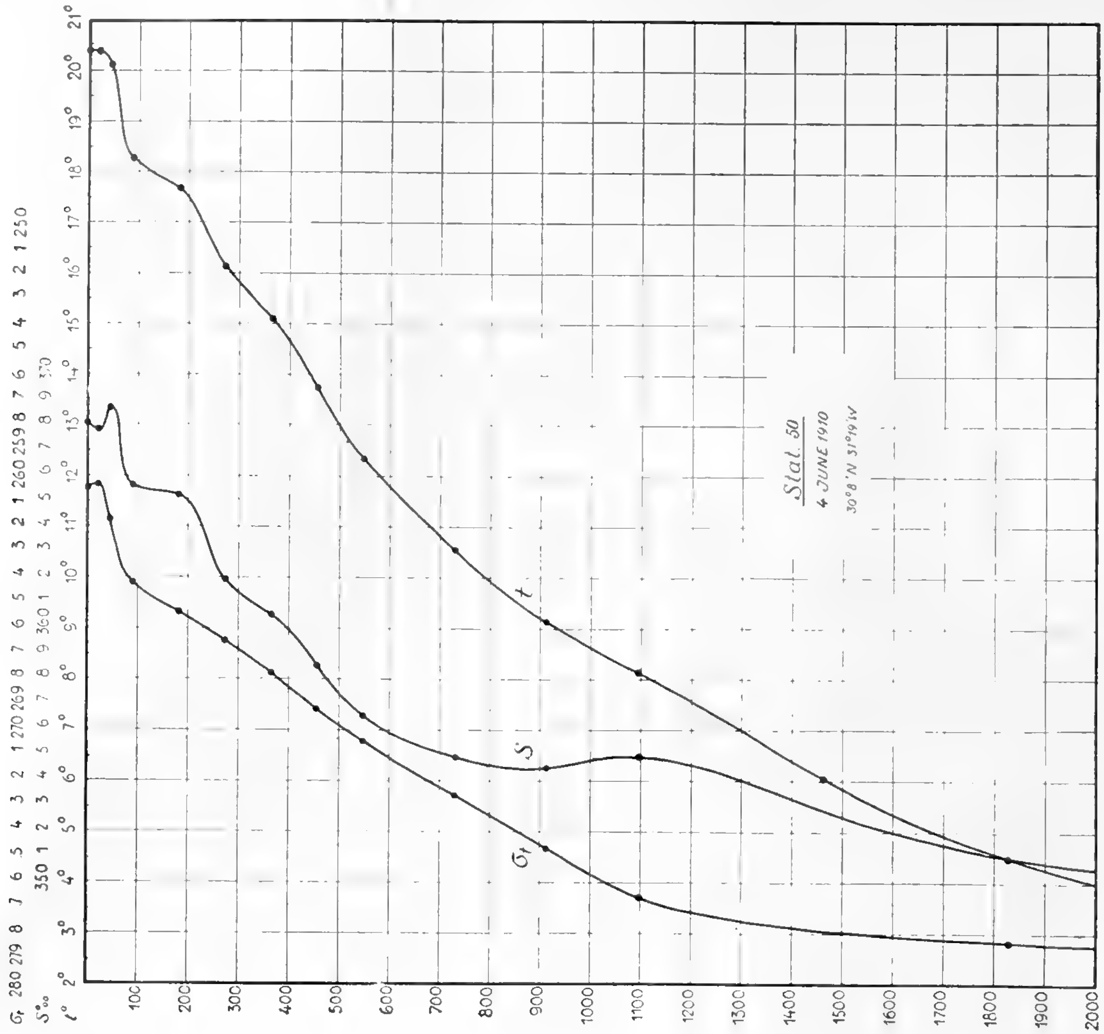

Stat. 23
5 MAY 1910
t
S
σ_t

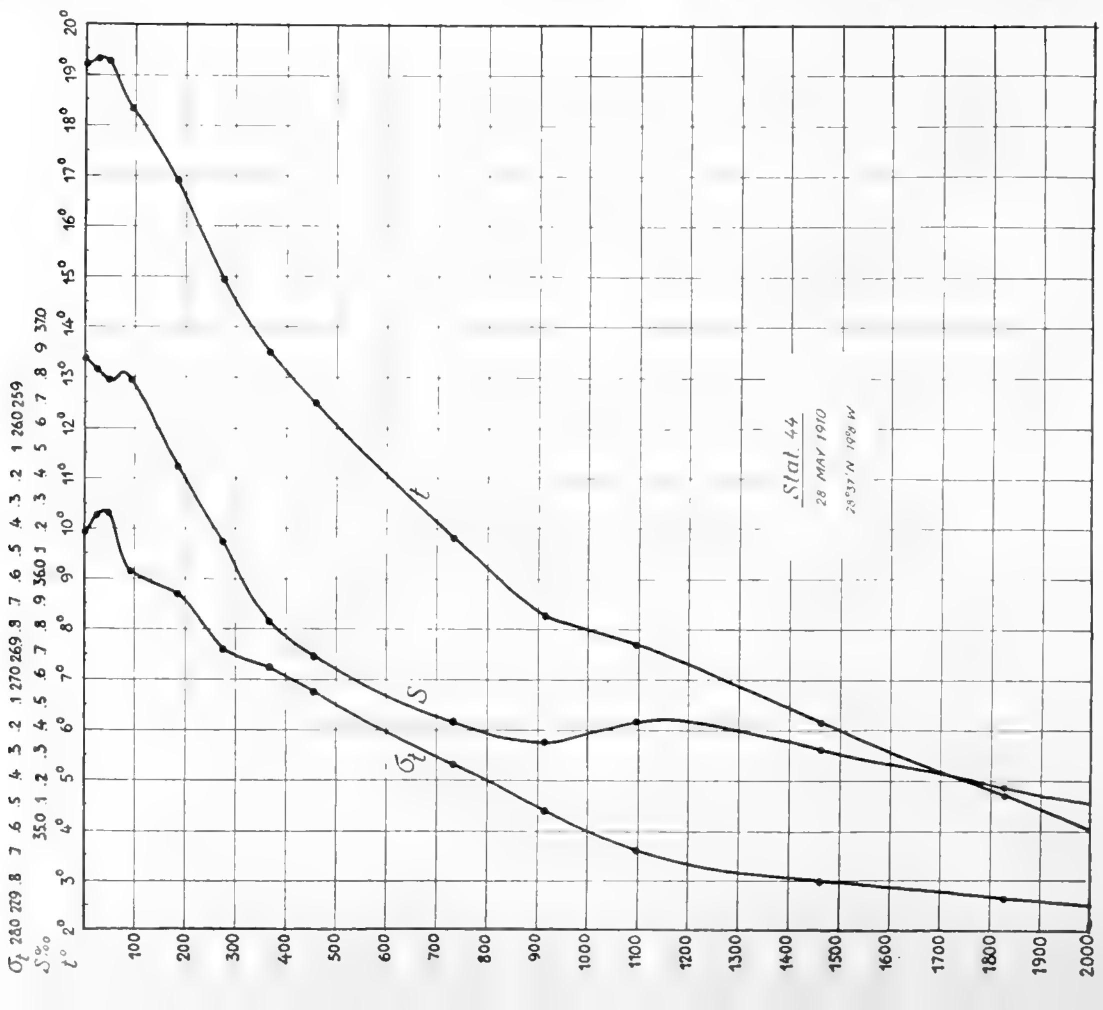

Stat. 29
9-10 MAY 1910
35°10'N 7°55'W

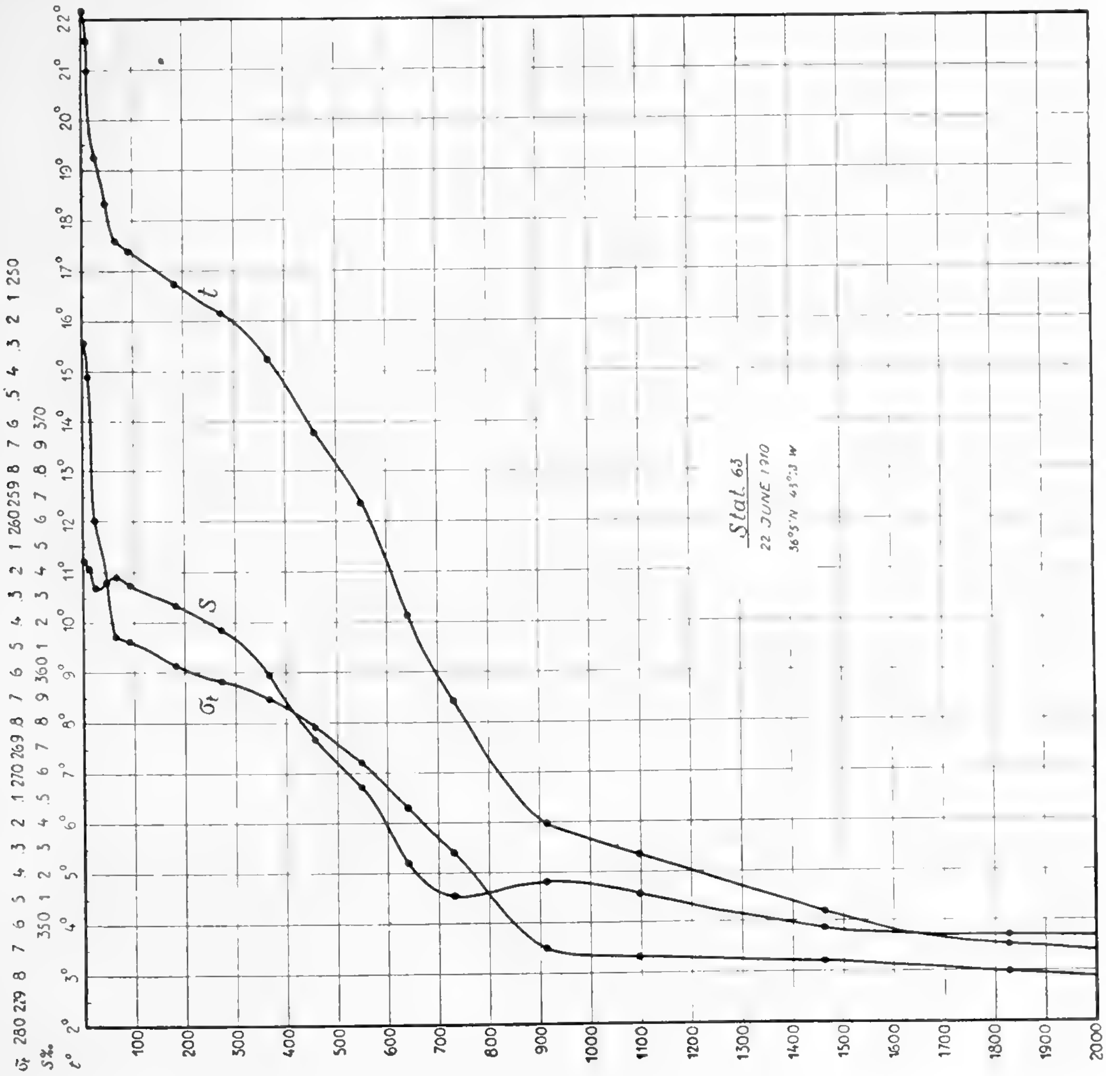

Stat. 40

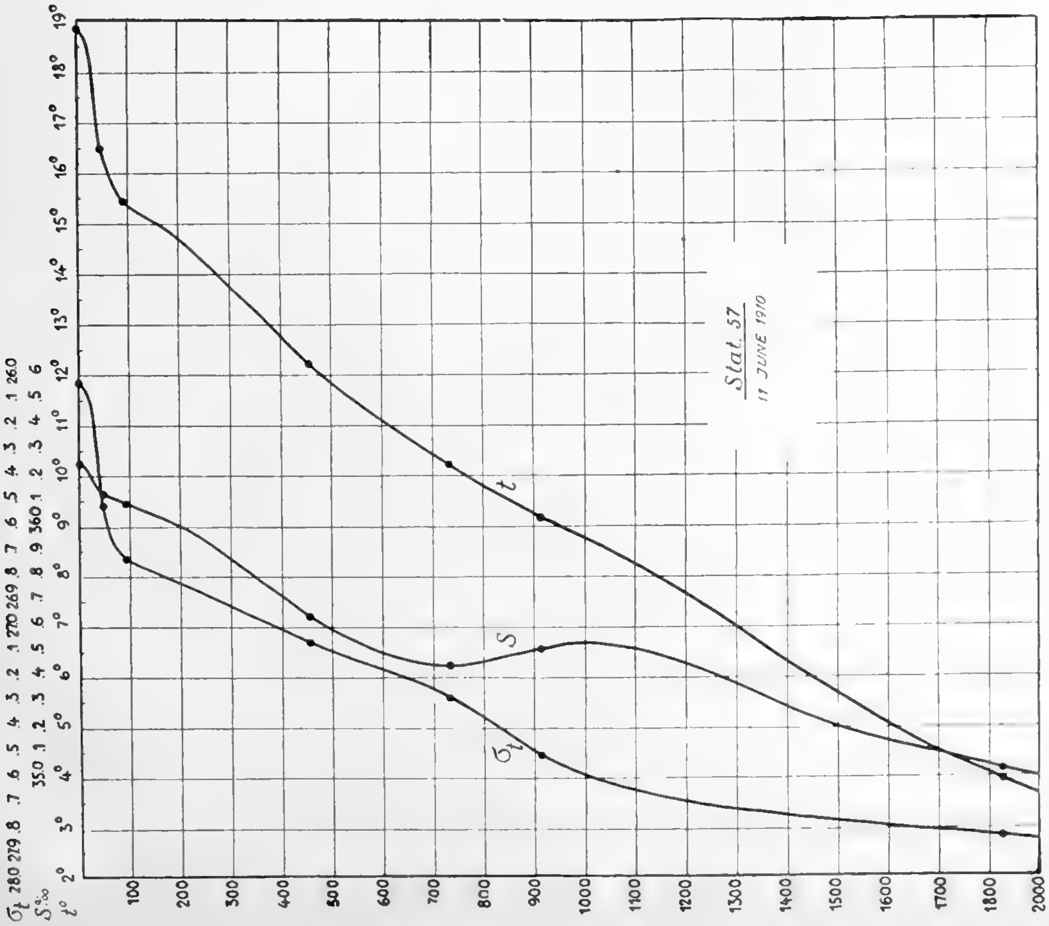

Stat. 28
9 MAY 1910
36°0'N 7°44'W

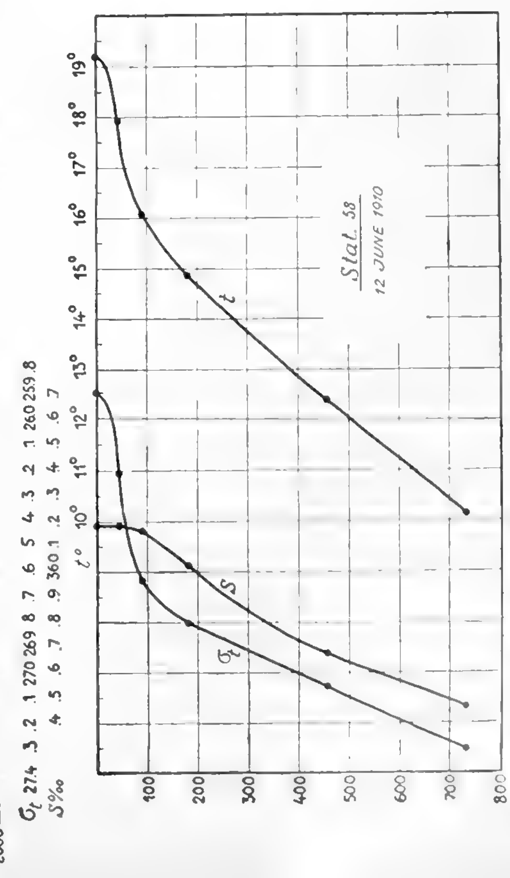

Stat. 30
10 MAY 1910
34°38'N 8°22'W

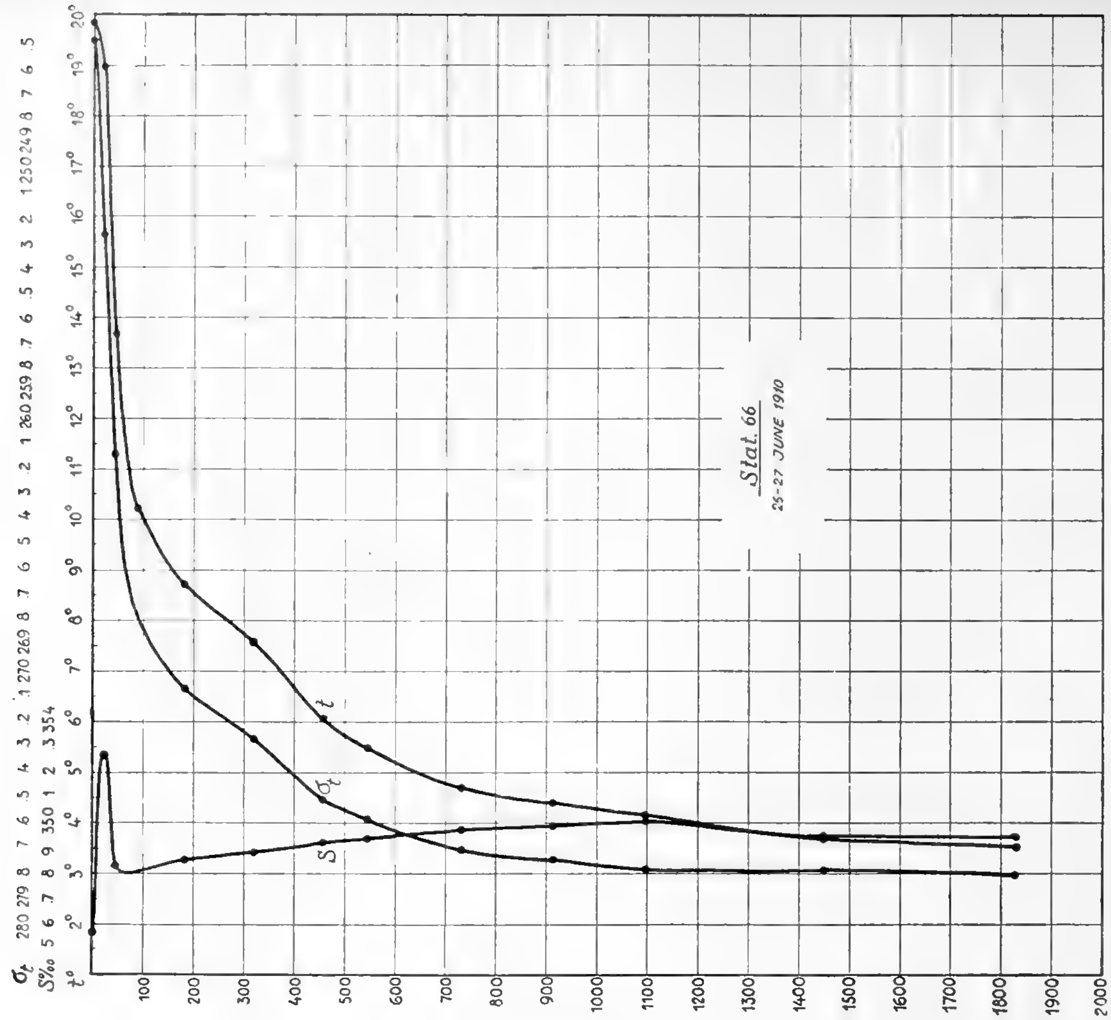

Stat. 50
4 JUNE 1910
t
S
σt

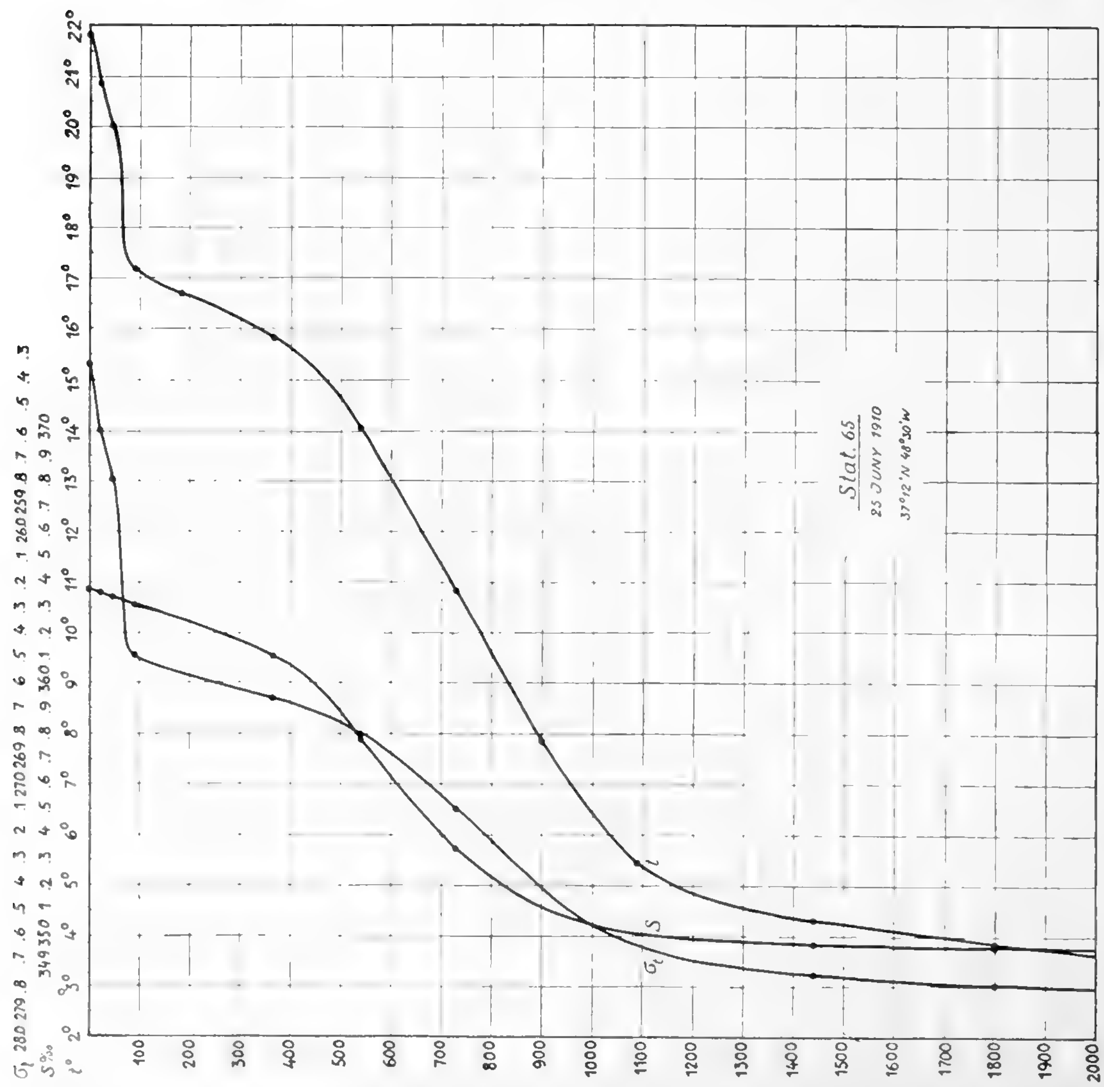

Stat. 44
28 MAY 1910
t
S
σt

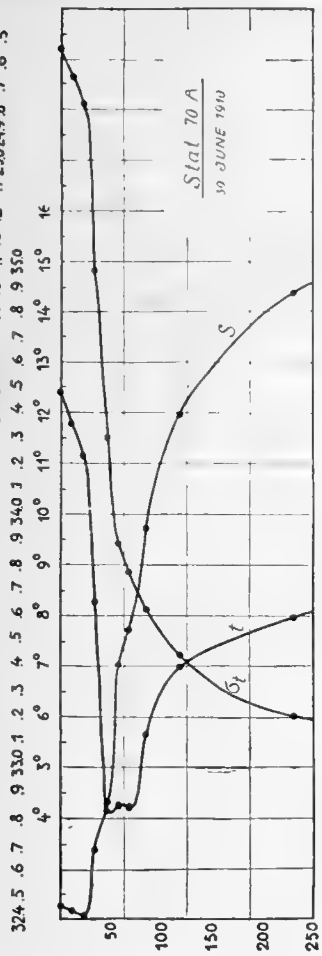

Stat. 63
22 JUNE 1910
t
S
σt

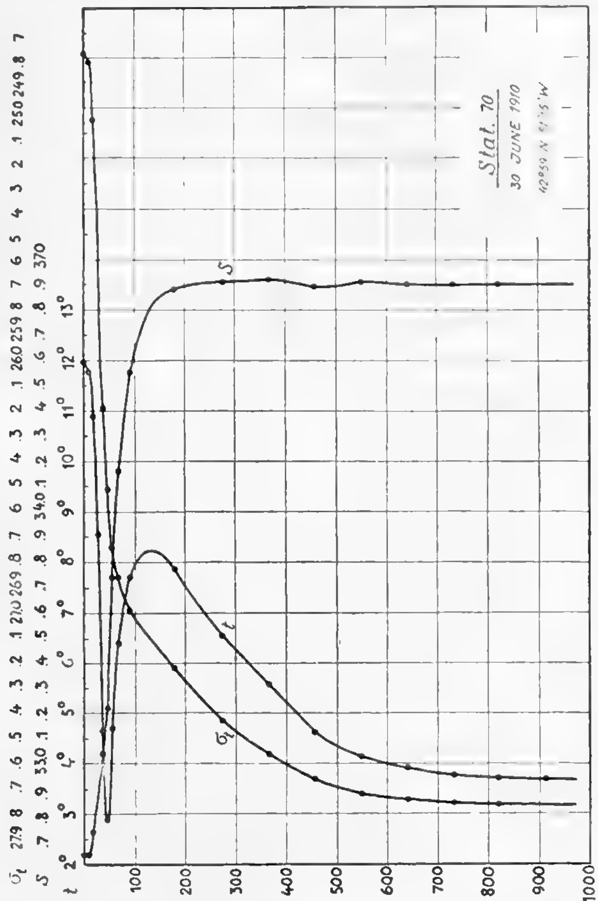

Stat. 57
11 JUNE 1910
t
S
σt

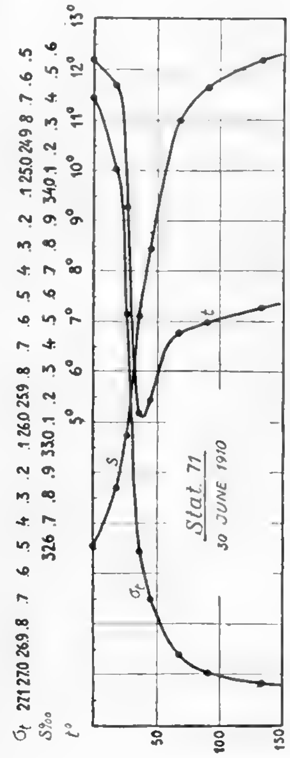

Stat. 58
12 JUNE 1910
t
S
σt

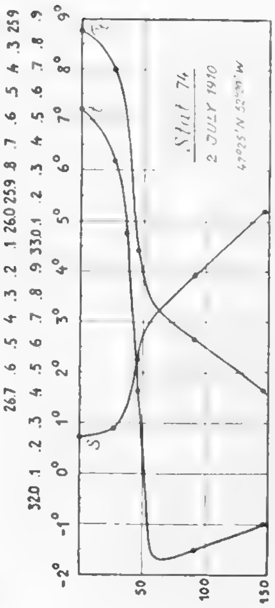

Stat. 66
25-27 JUNE 1910
t
σ_t
S

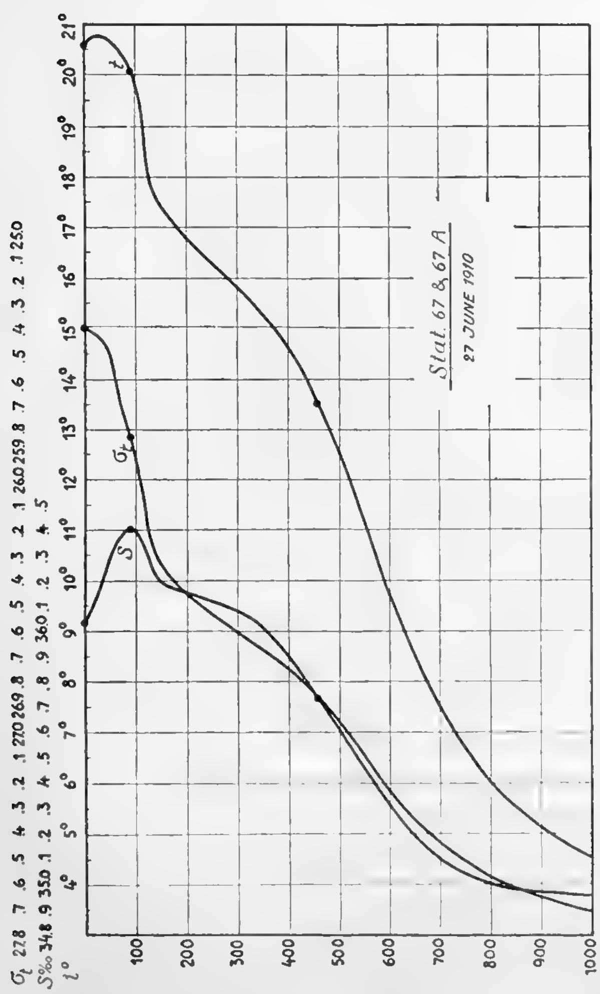

Stat. 65
25 JUNY 1910
37°12'N 48°30'W
t
S
σ_t

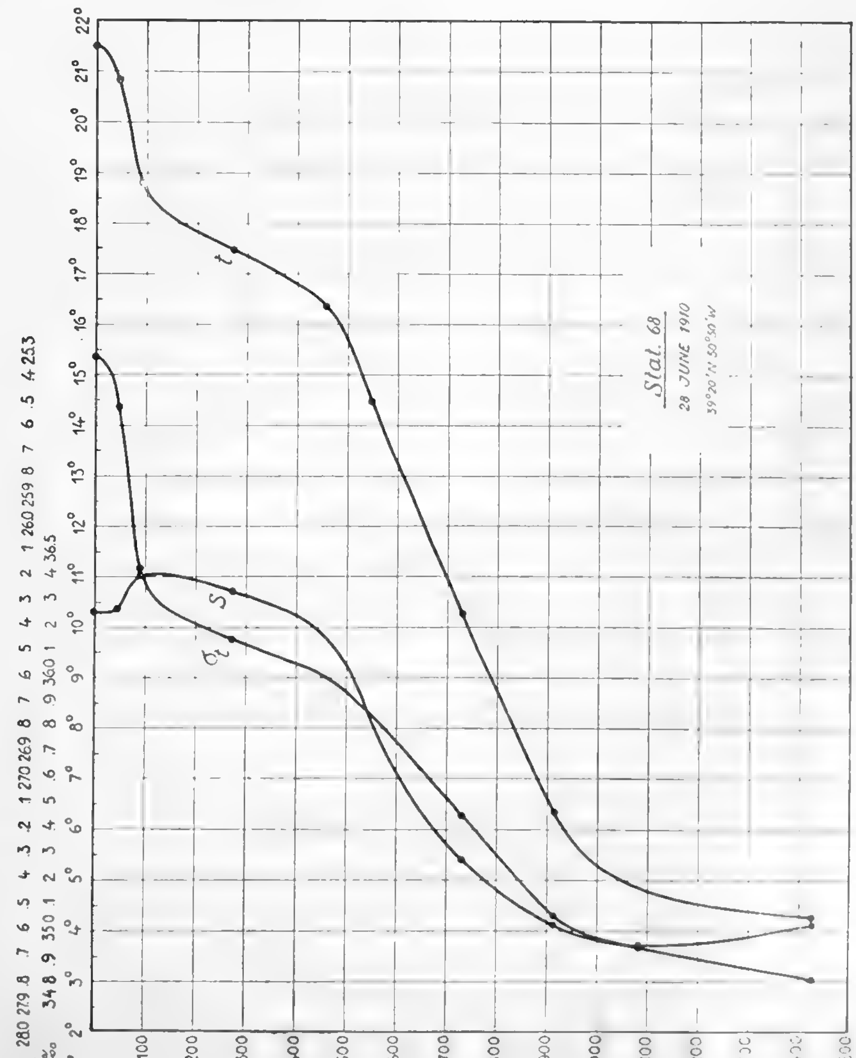

Stat. 70 A
30 JUNE 1910

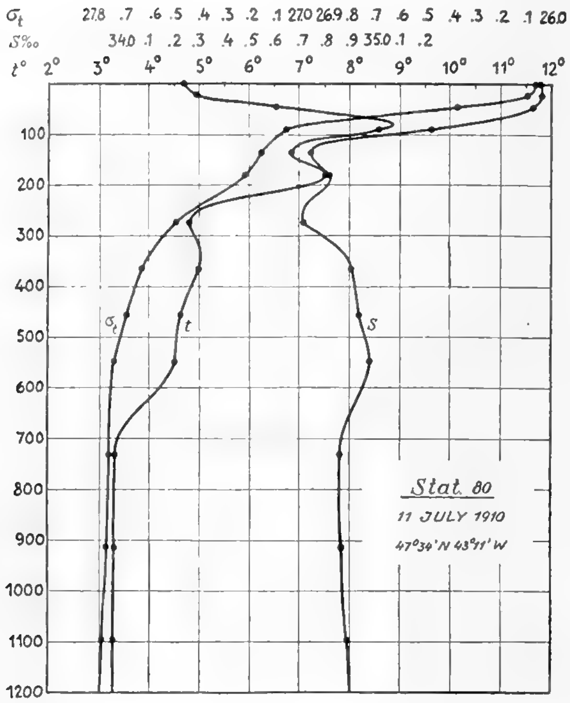

Stat. 70
30 JUNE 1910

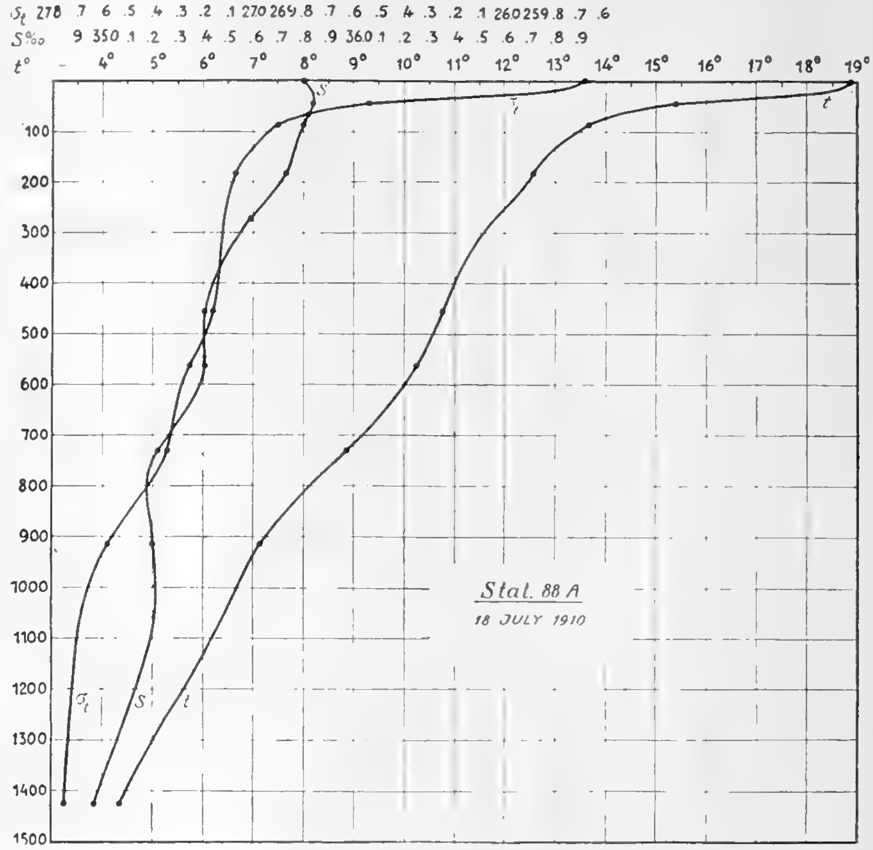

Stat. 71
30 JUNE 1910

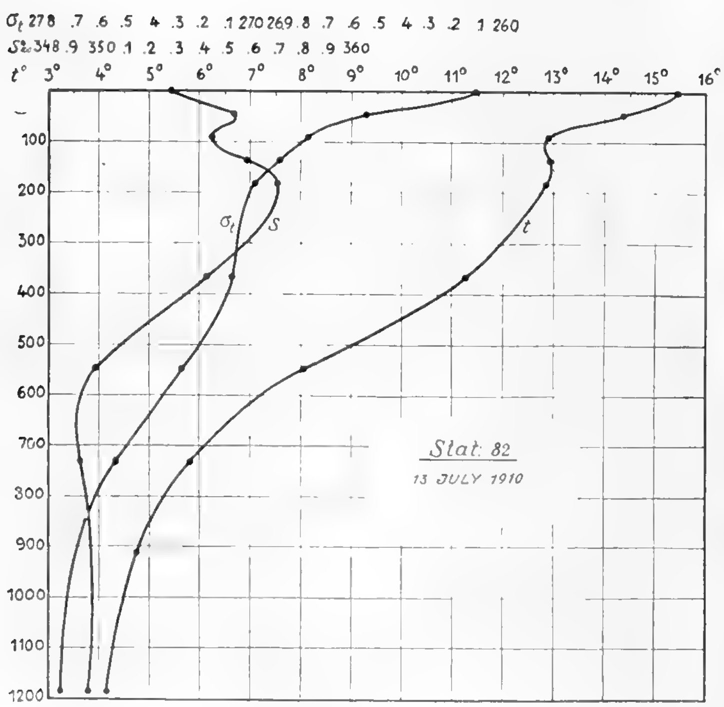

Stat. 74
2 JULY 1910

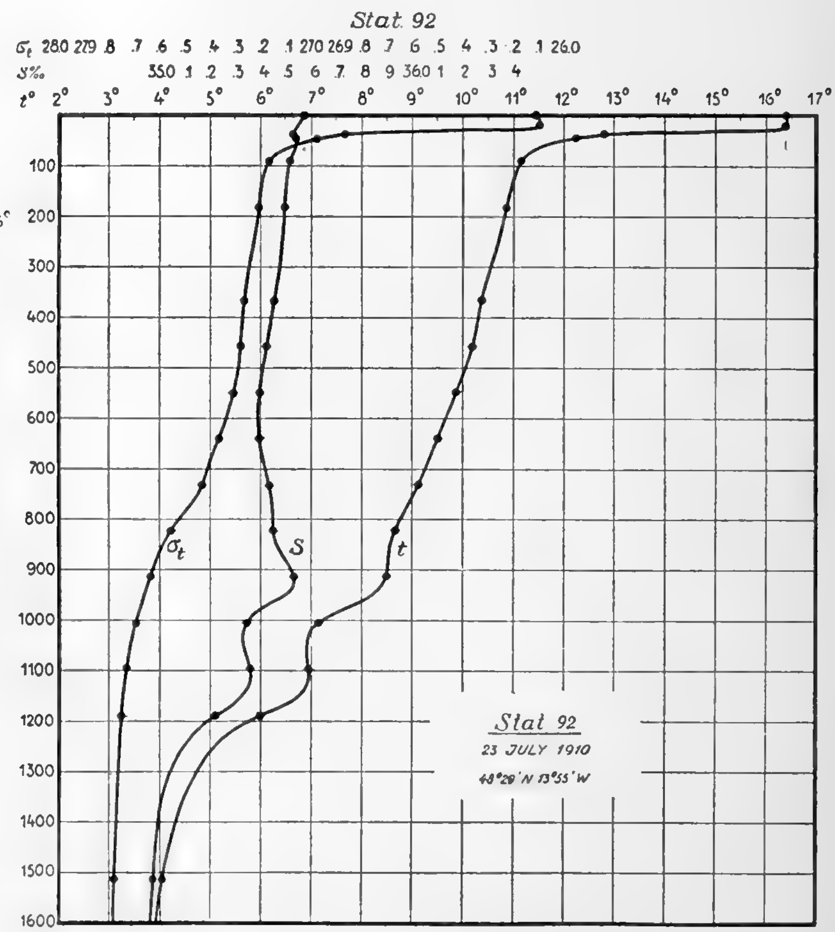

Stat. 67 & 67 A
27 JUNE 1910

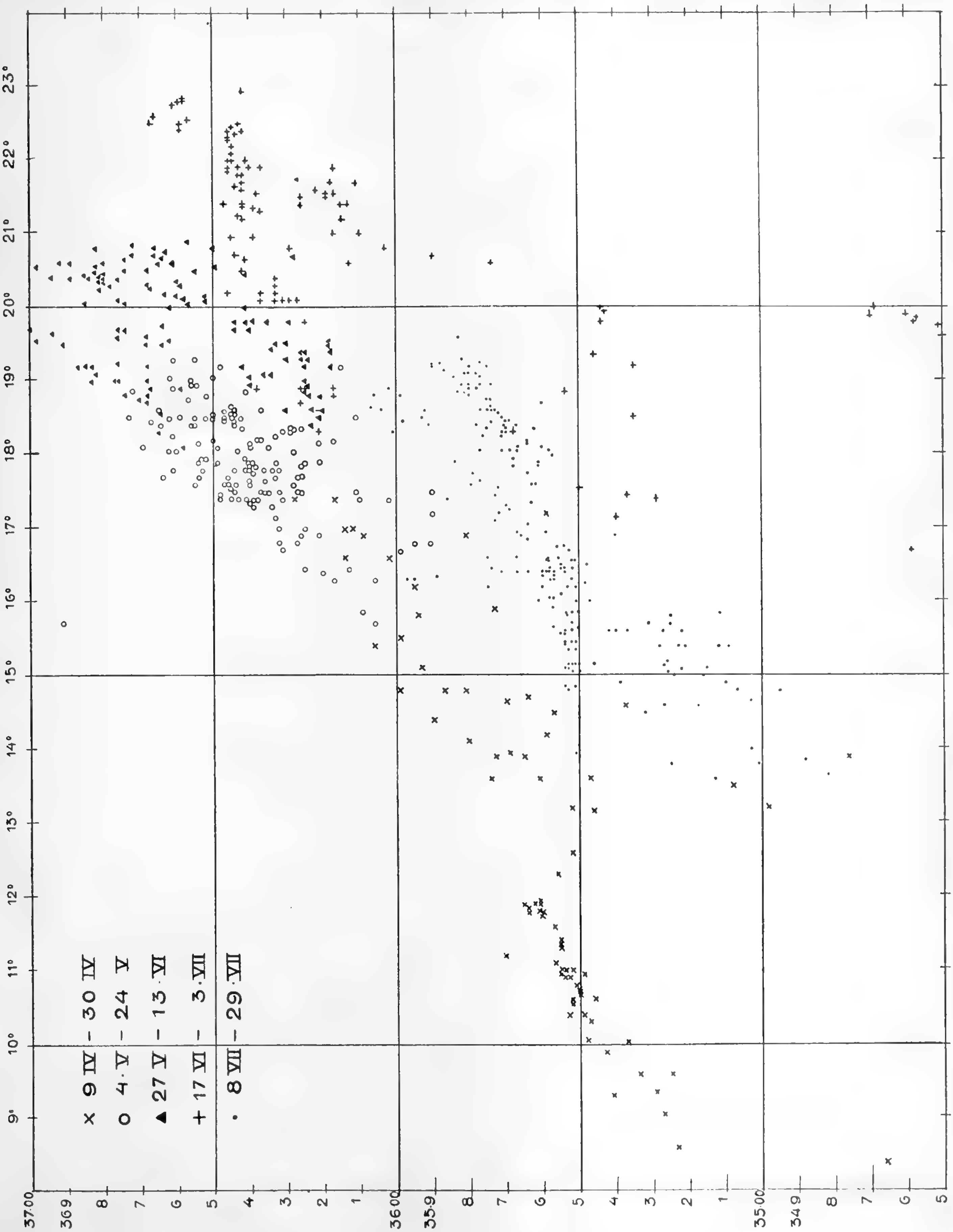

Stat. 68
28 JUNE 1910


Stat. 80
11 JULY 1910
47°34'N 43°11'W
σ_t
t
S

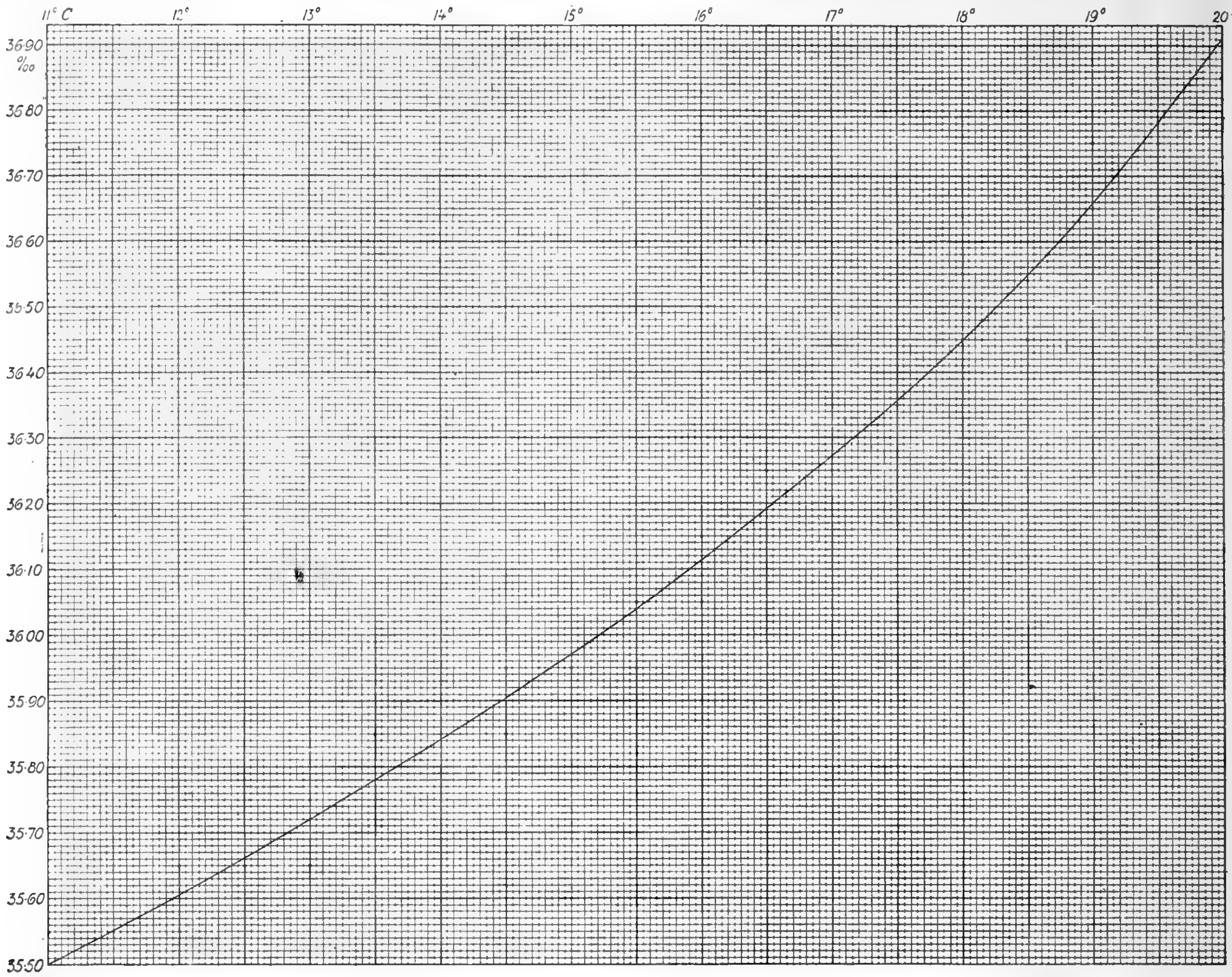

Stat. 88 A
18 JULY 1910
σ_t
S
t

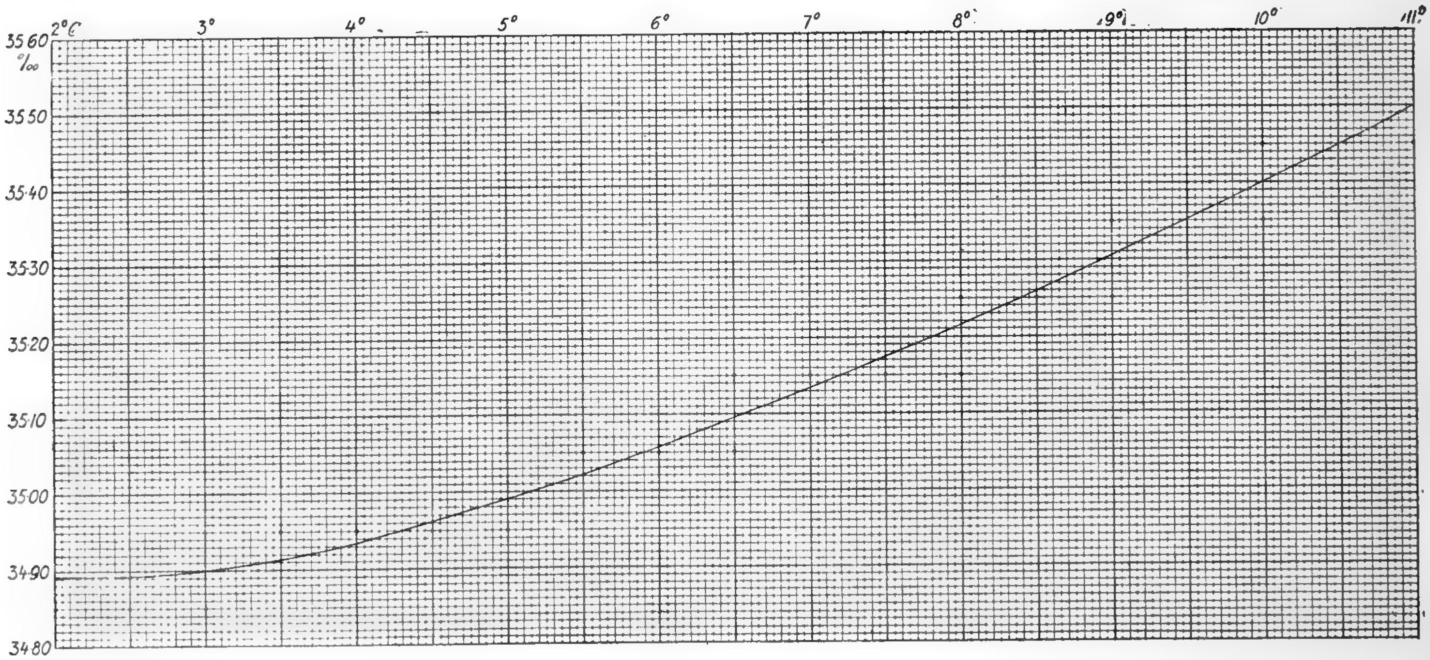

Stat. 82
13 JULY 1910
σ_t
S
t

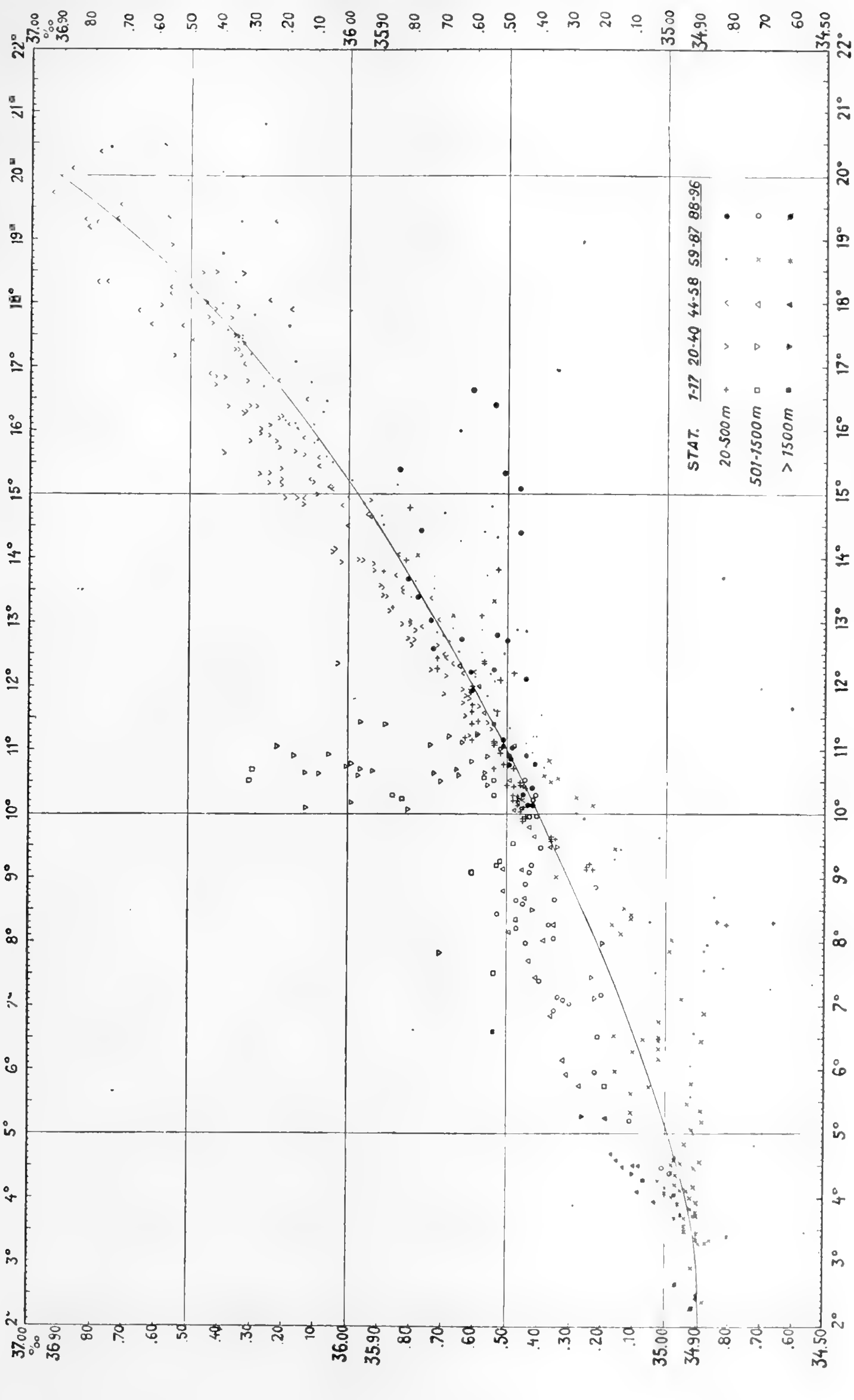

Stat. 92
Stat. 92
23 JULY 1910
48°29'N 13°55'W
σ_t
S
t

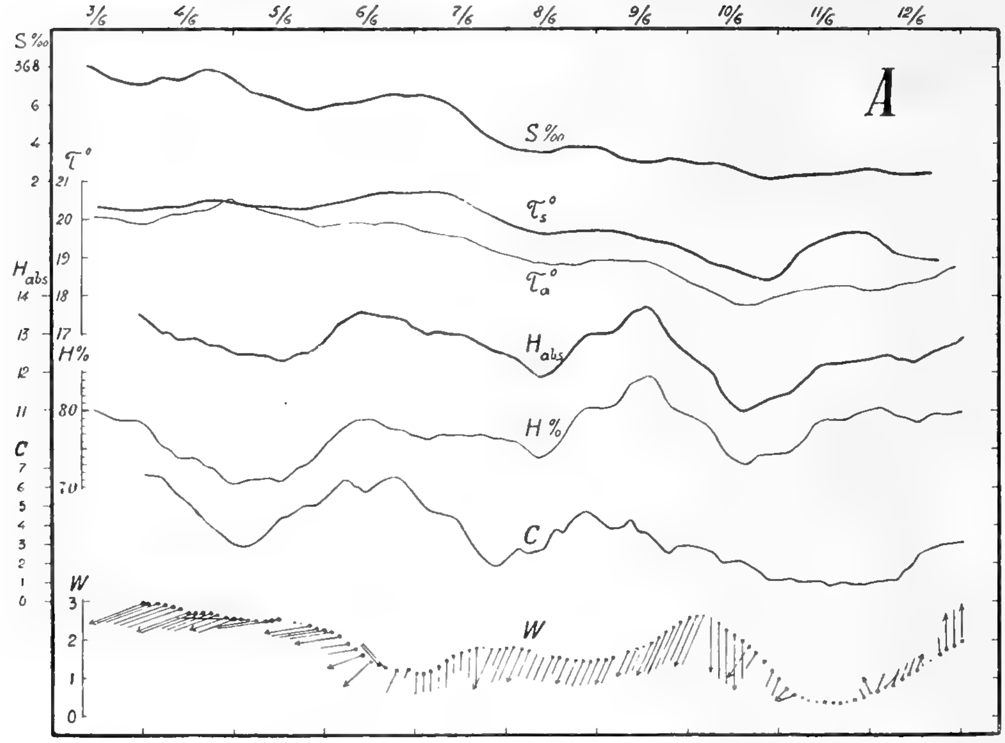


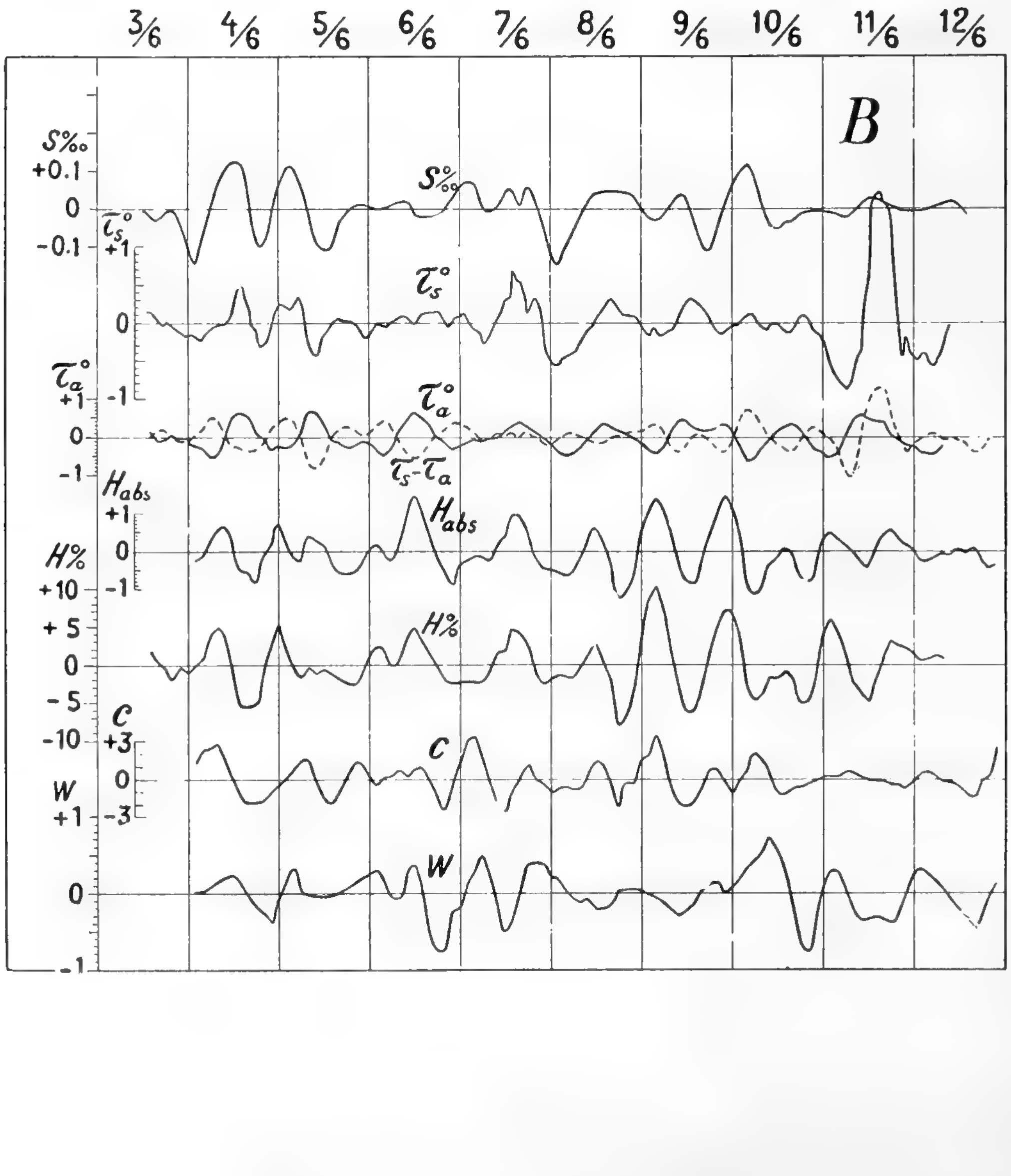
9° 10° 11° 12° 13° 14° 15° 16° 17° 18° 19° 20° 21° 22° 23°
37.00 36.9 8 7 6 5 4 3 2 1 36.00 35.9 8 7 6 5 4 3 2 1 35.00 34.9 8 7 6 5
× 9 IV - 30 IV
o 4 V - 24 V
▲ 27 V - 13 VI
+ 17 VI - 3 VII
· 8 VII - 29 VII


11° C
12°
13°
14°
15°
16°
17°
18°
19°
20°
36.90 ‰
36.80
36.70
36.60
36.50
36.40
36.30
36.20
36.10
36.00
35.90
35.80
35.70
35.60
35.50

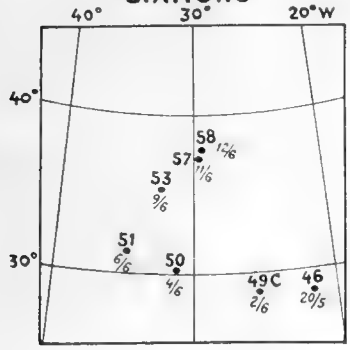

2° C
3°
4°
5°
6°
7°
8°
9°
10°
11°
35.60 ‰
35.50
35.40
35.30
35.20
35.10
35.00
34.90
34.80


STAT. 1-17 20-40 44-58 59-87 88-96
20-500 m
501-1500 m
> 1500 m

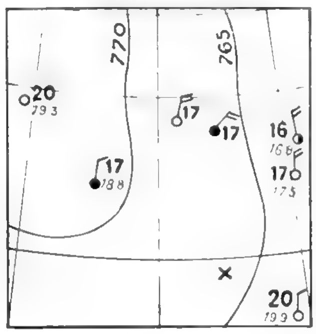

A
S ‰
τ_s°
τ_a°
H_{abs}
H %
C
W


B
S‰
τ_s°
τ_a°
τ_s-τ_a
H_{abs}
H%
C
W

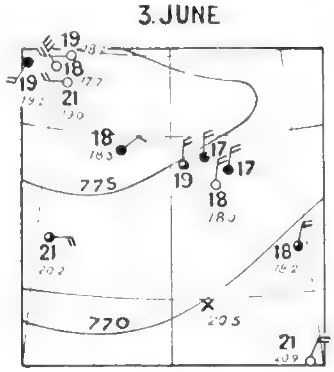
STATIONS



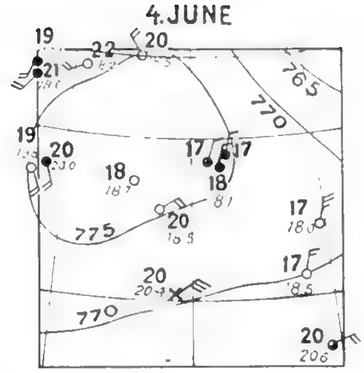
2. JUNE



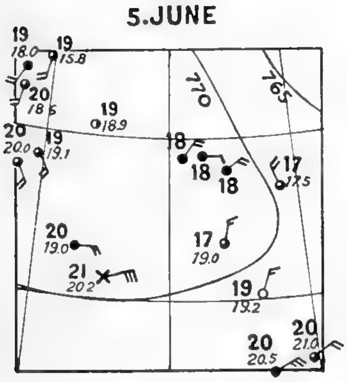
3. JUNE



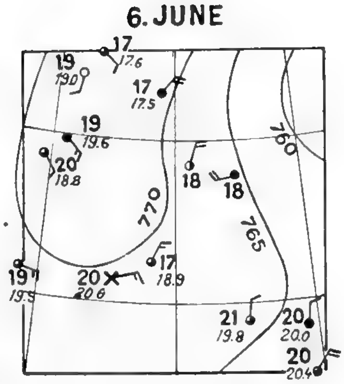
4. JUNE



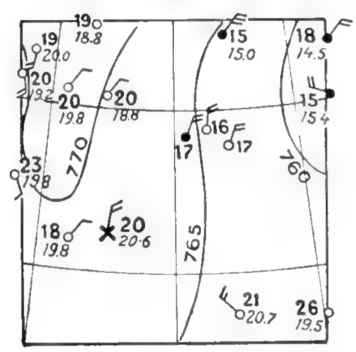
5. JUNE



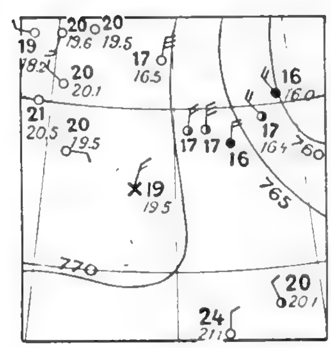
6. JUNE



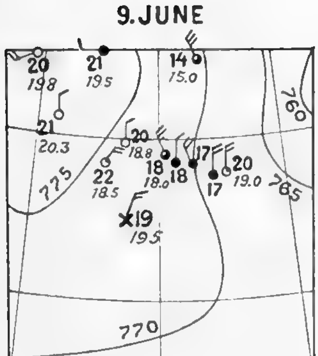
7. JUNE



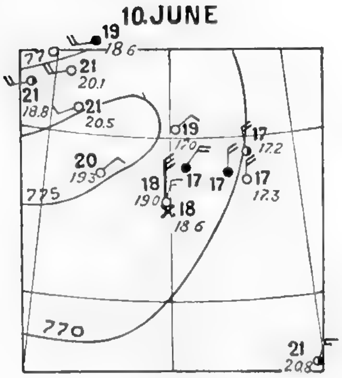
8. JUNE



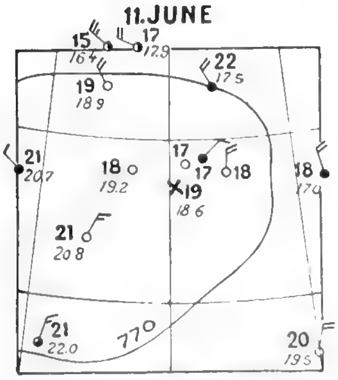
9. JUNE



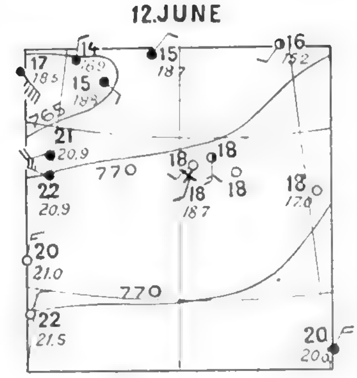
10. JUNE

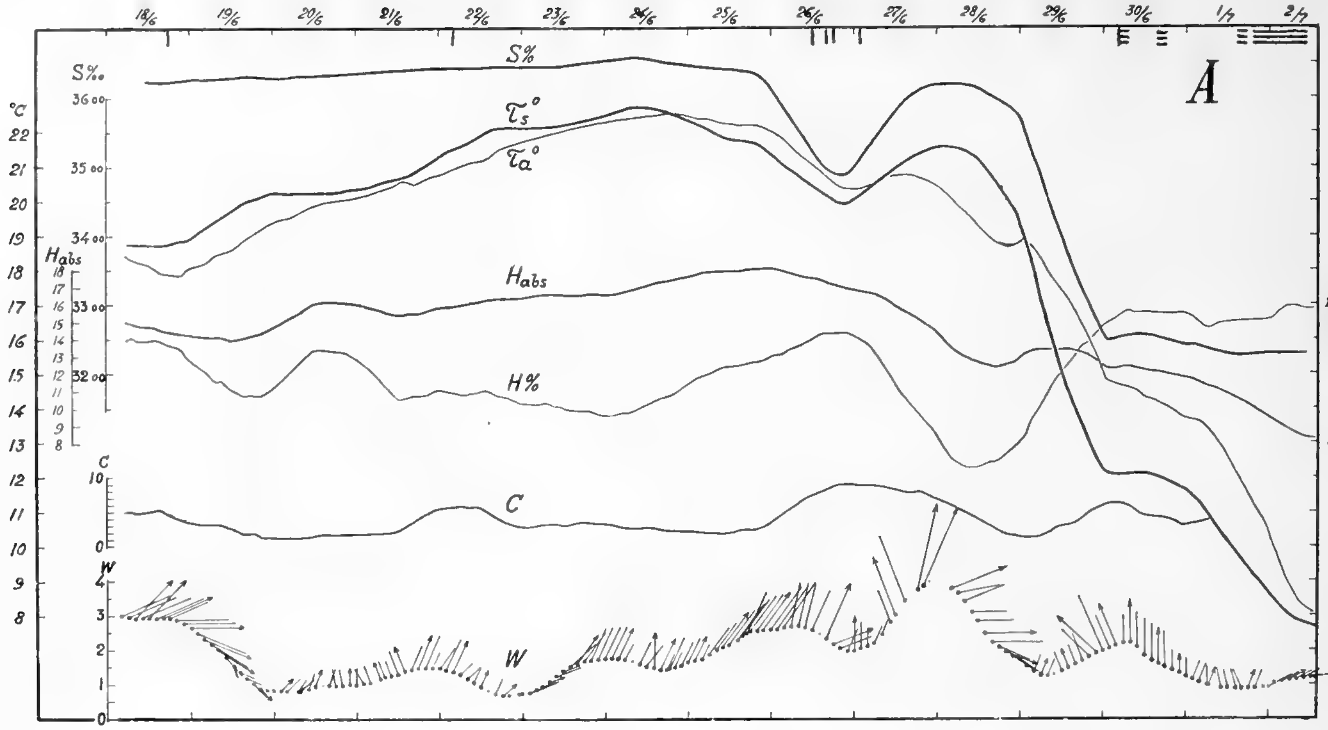


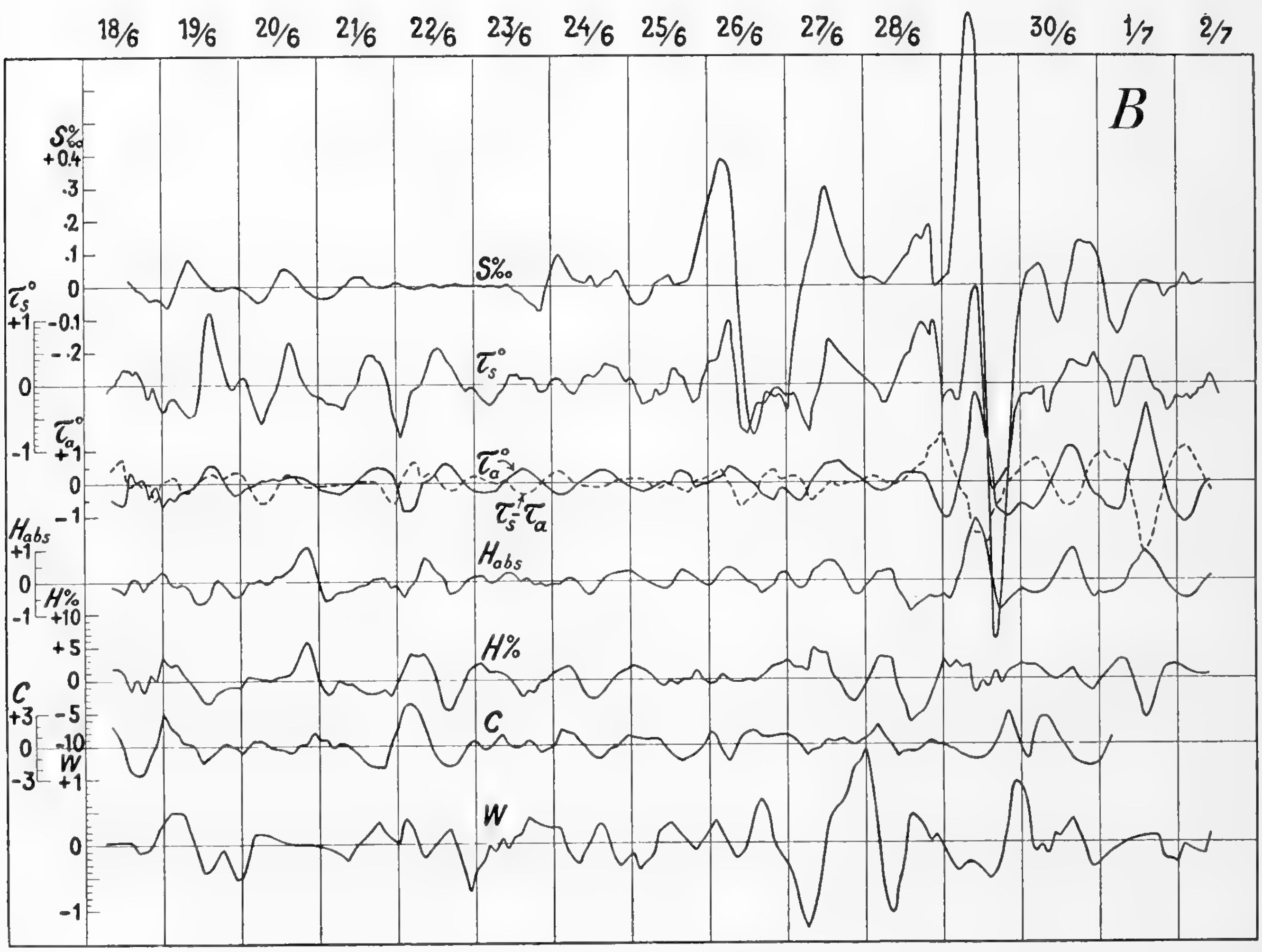
11. JUNE



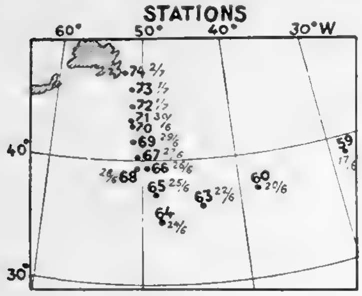
12. JUNE



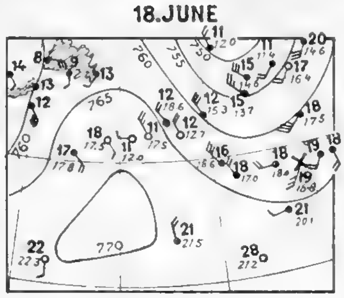




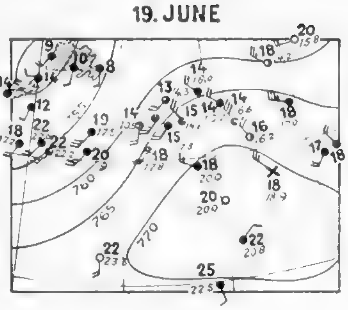
STATIONS



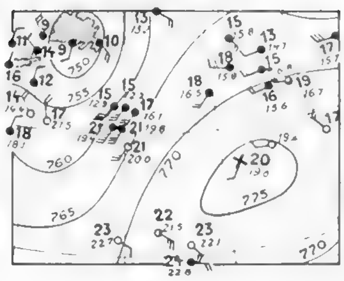
18. JUNE



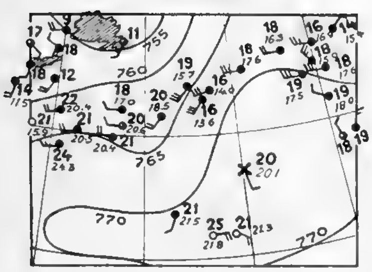
19. JUNE



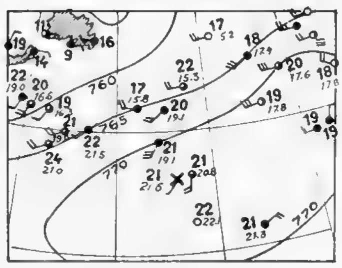
20. JUNE



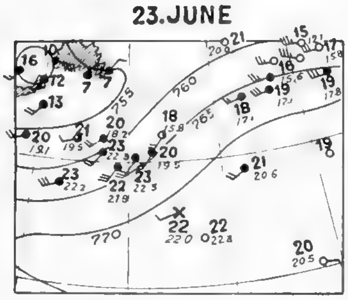
21. JUNE



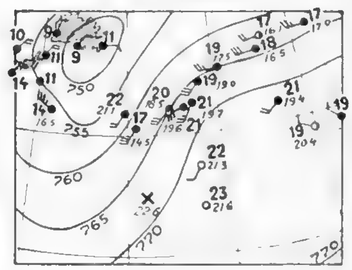
22. JUNE



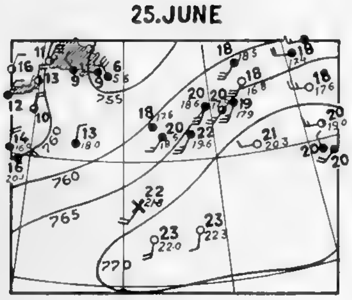
23. JUNE



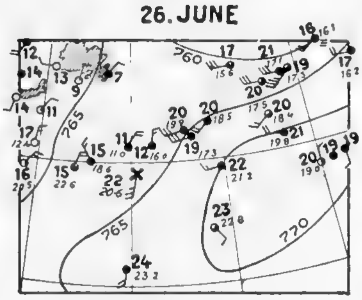
24. JUNE



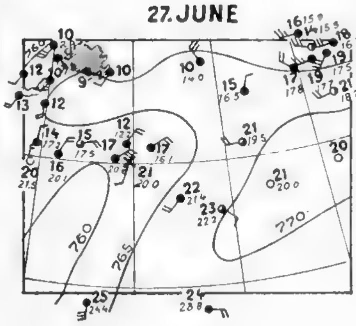
25. JUNE



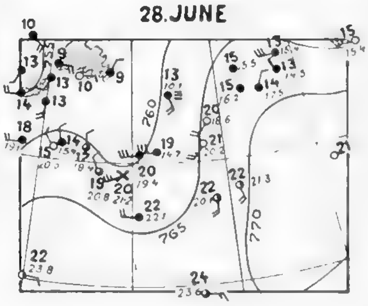
26. JUNE



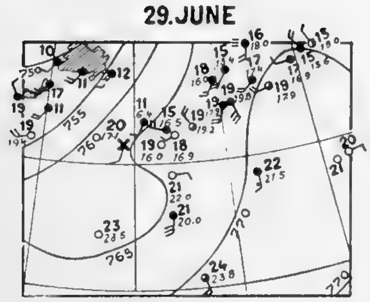
27. JUNE



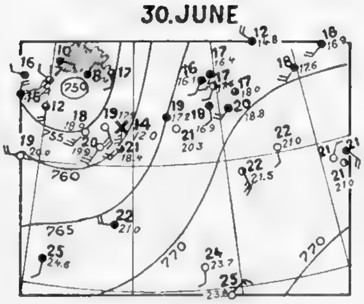
28. JUNE



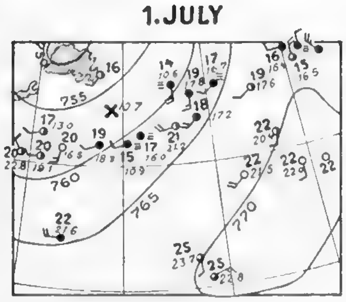
29. JUNE



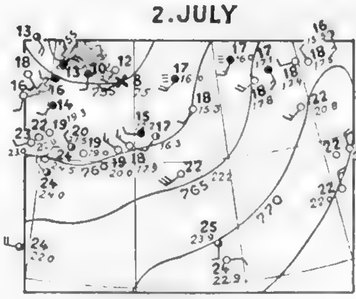
30. JUNE

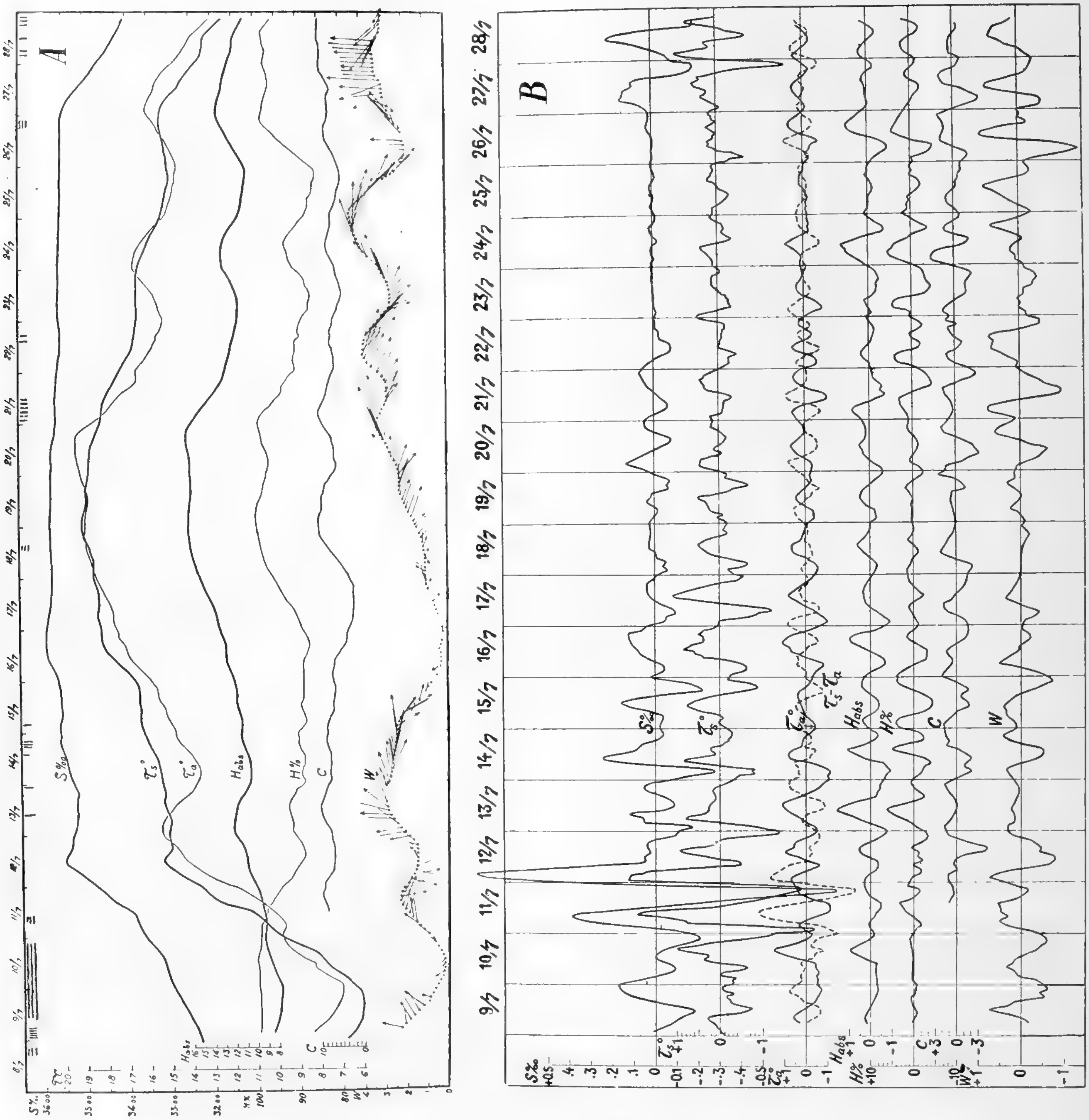


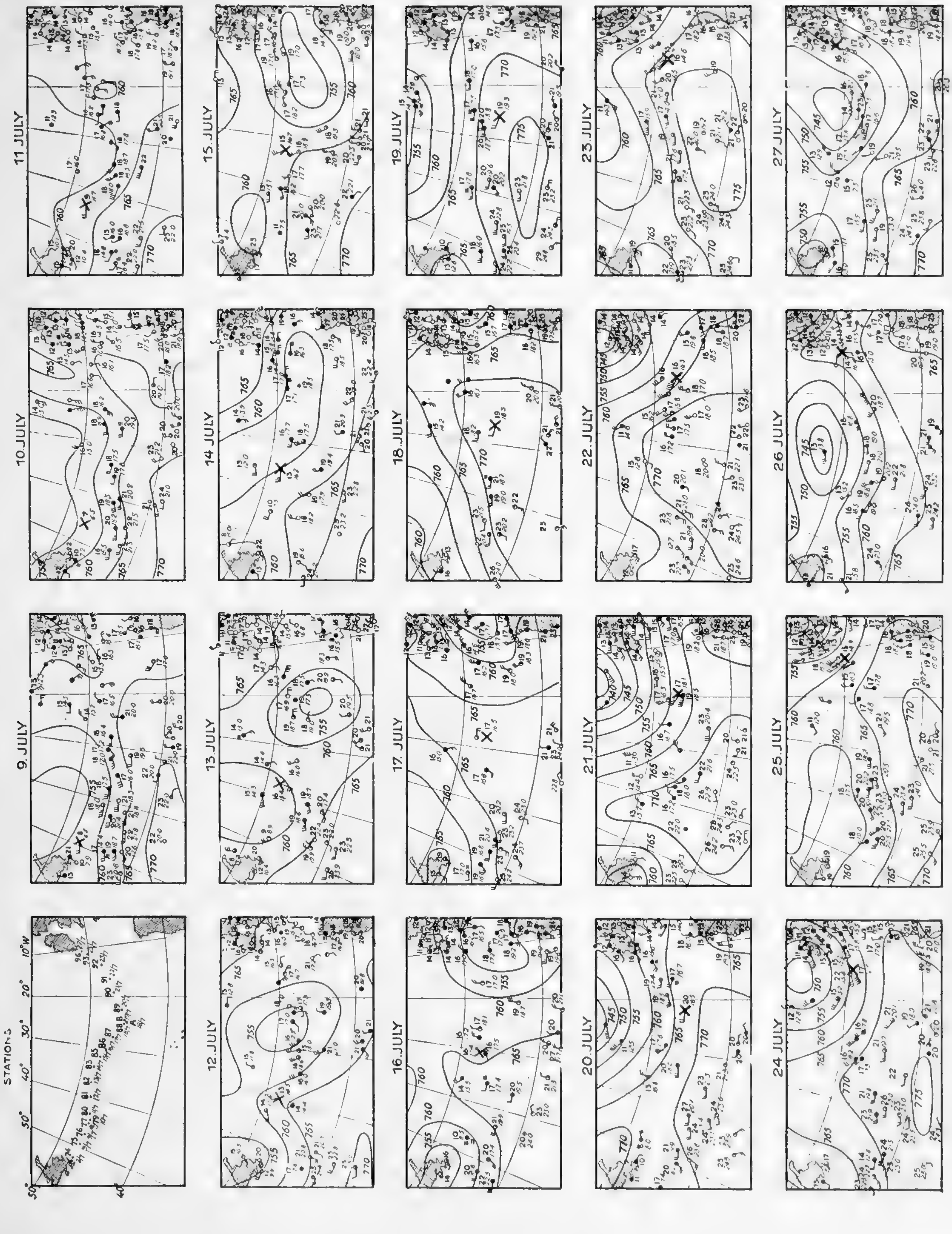
1. JULY

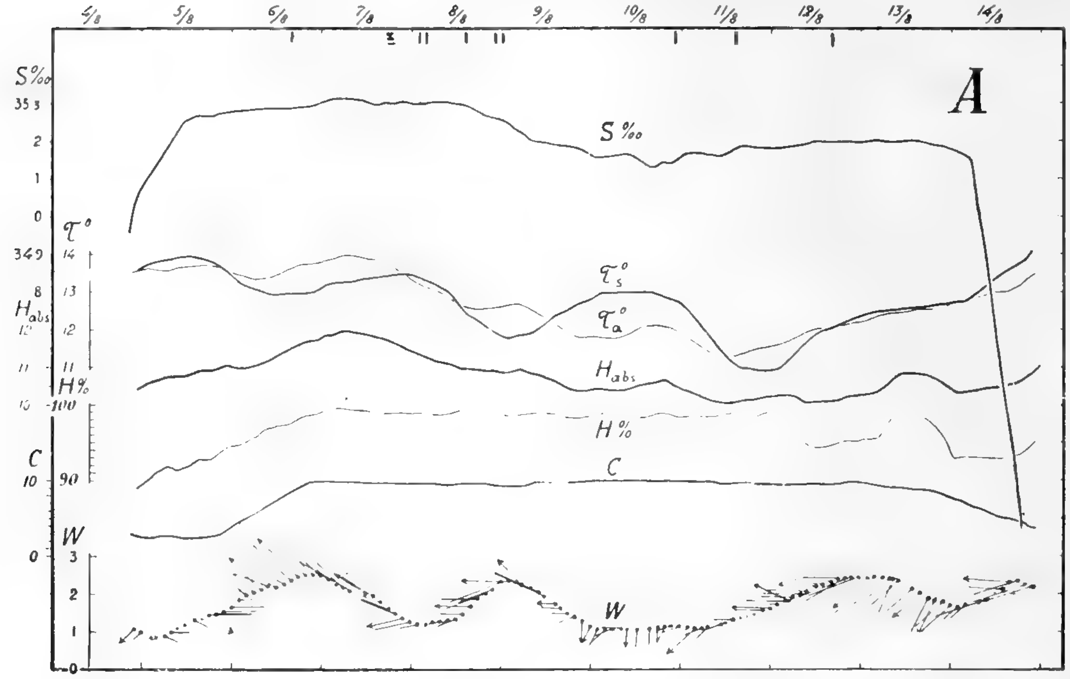


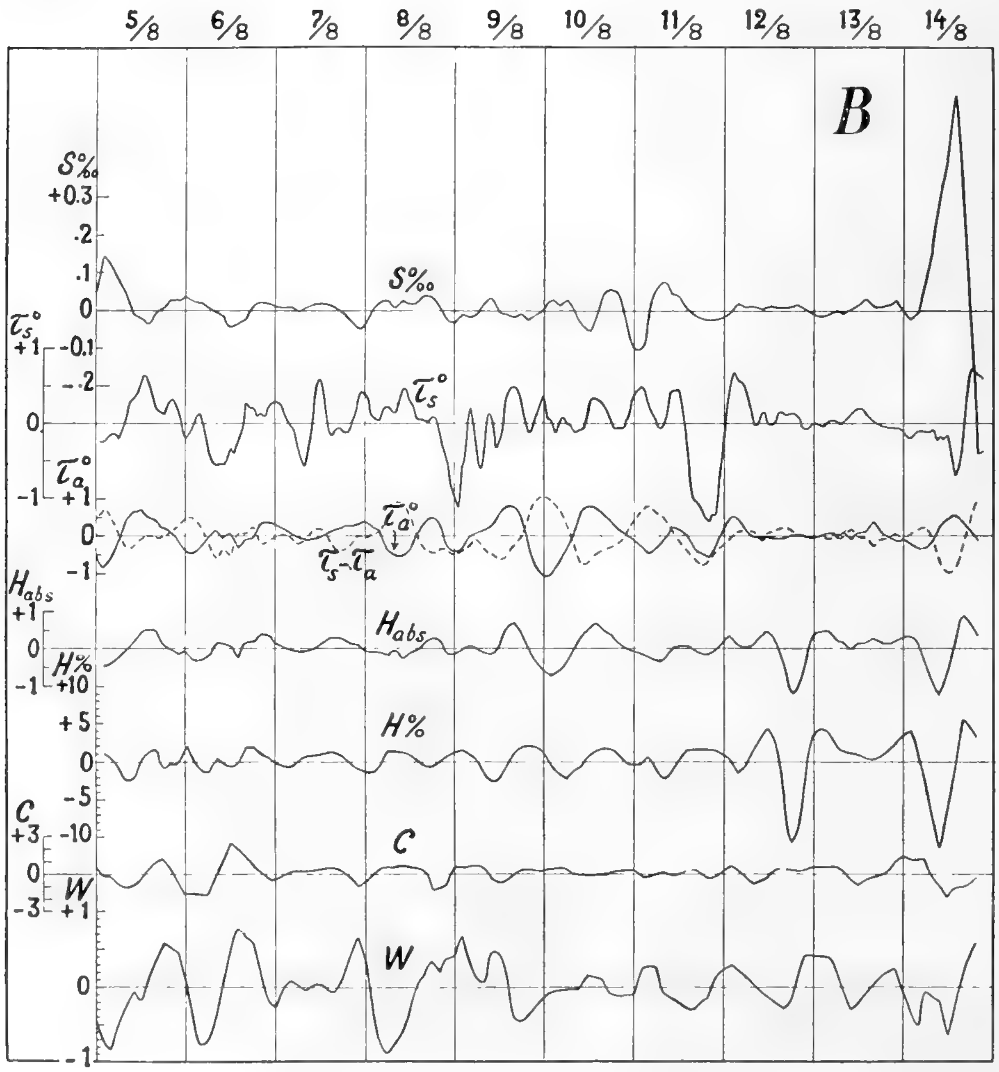
2. JULY



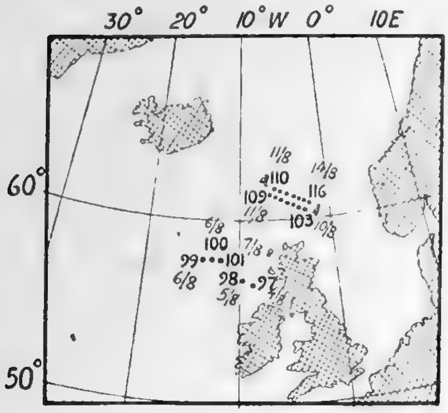

A
B
9/7
10/7
11/7
12/7
13/7
14/7
15/7
16/7
17/7
18/7
19/7
20/7
21/7
22/7
23/7
24/7
25/7
26/7
27/7
28/7
H%
C
W


STATIONS
9. JULY
10. JULY
11 JULY
12. JULY
13. JULY
14. JULY
15. JULY
16. JULY
17. JULY
18. JULY
19. JULY
20. JULY
21. JULY
22. JULY
23. JULY
24. JULY
25. JULY
26. JULY
27. JULY

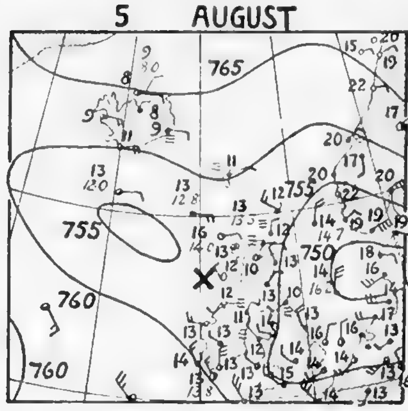

A
4/8
5/8
6/8
7/8
8/8
9/8
10/8
11/8
12/8
13/8
14/8
S ‰
τ°s
τ°a
H abs
H %
C
W


B
5/8
6/8
7/8
8/8
9/8
10/8
11/8
12/8
13/8
14/8
S‰
τ°s
τ°a
τs-τa
H abs
H%
C
W

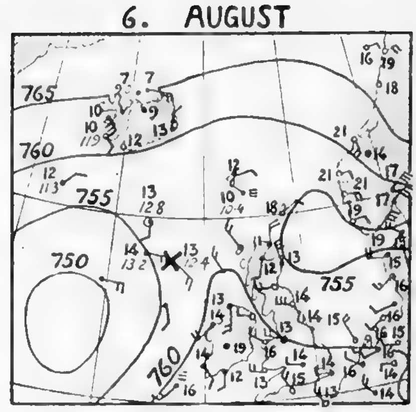
STATIONS



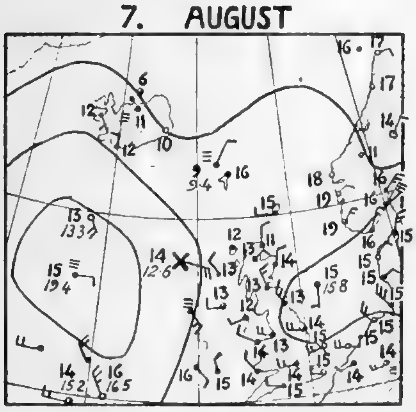
5 AUGUST



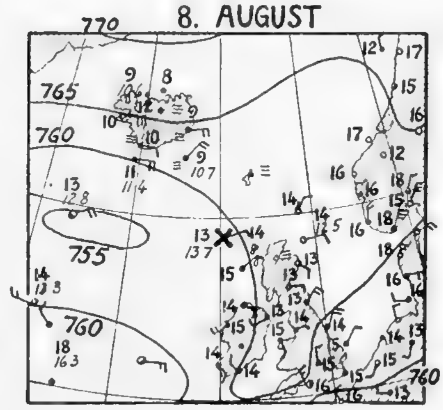
6. AUGUST



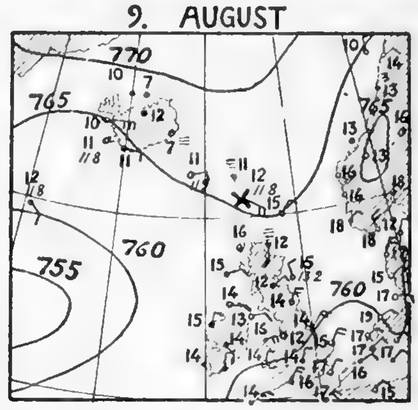
7. AUGUST



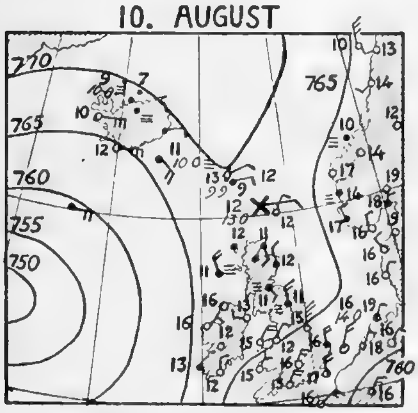
8. AUGUST



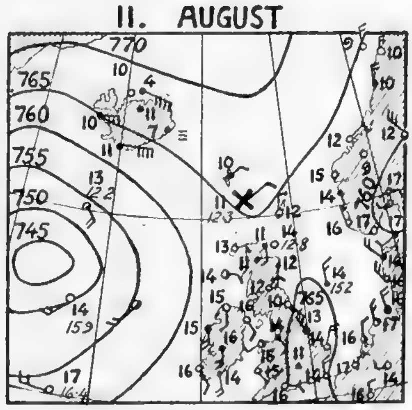
9. AUGUST



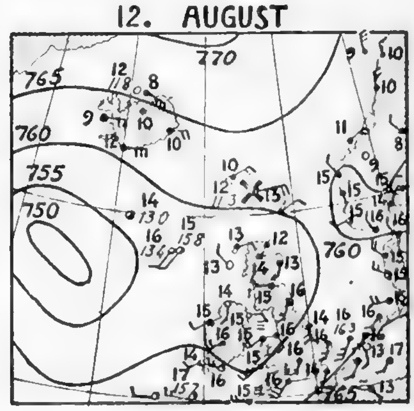
10. AUGUST



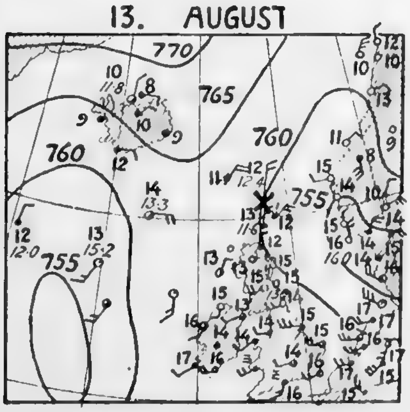
11. AUGUST



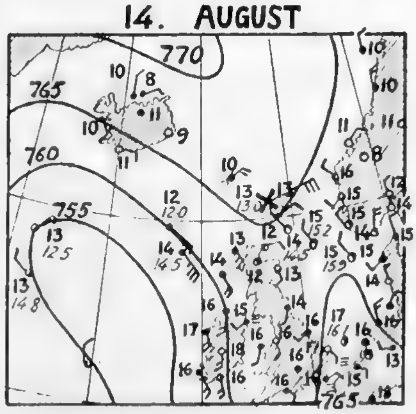
12. AUGUST



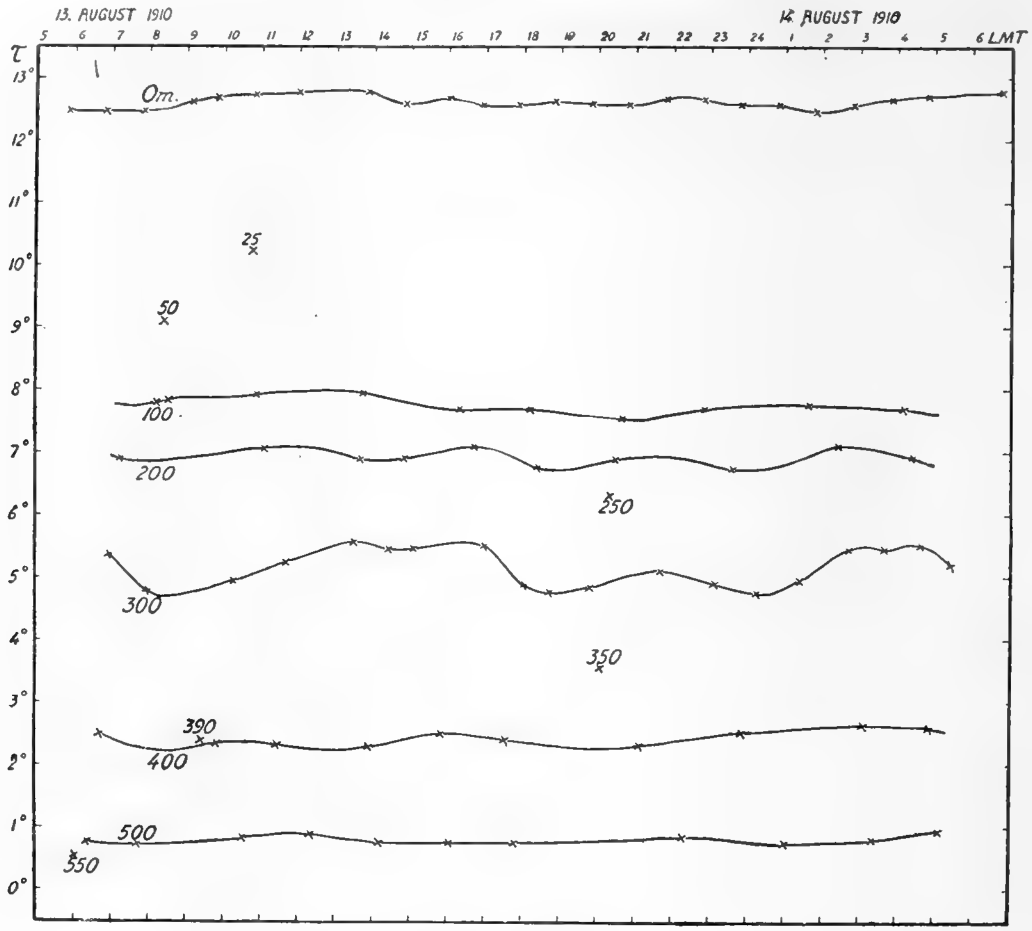
13. AUGUST



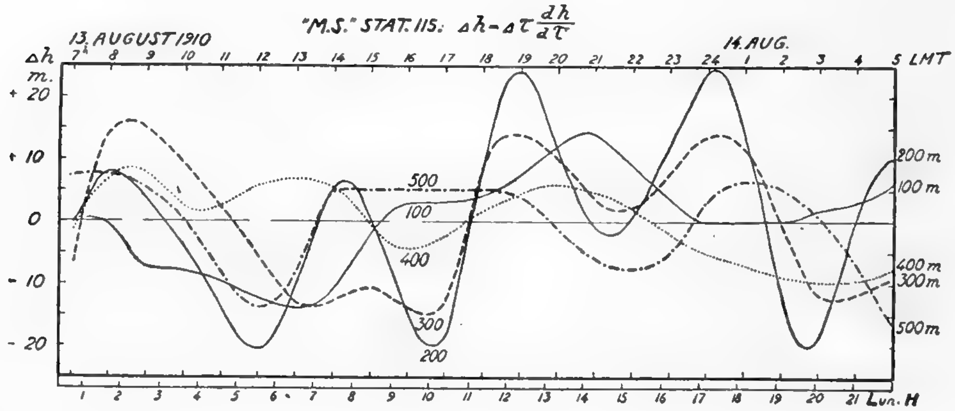
14. AUGUST



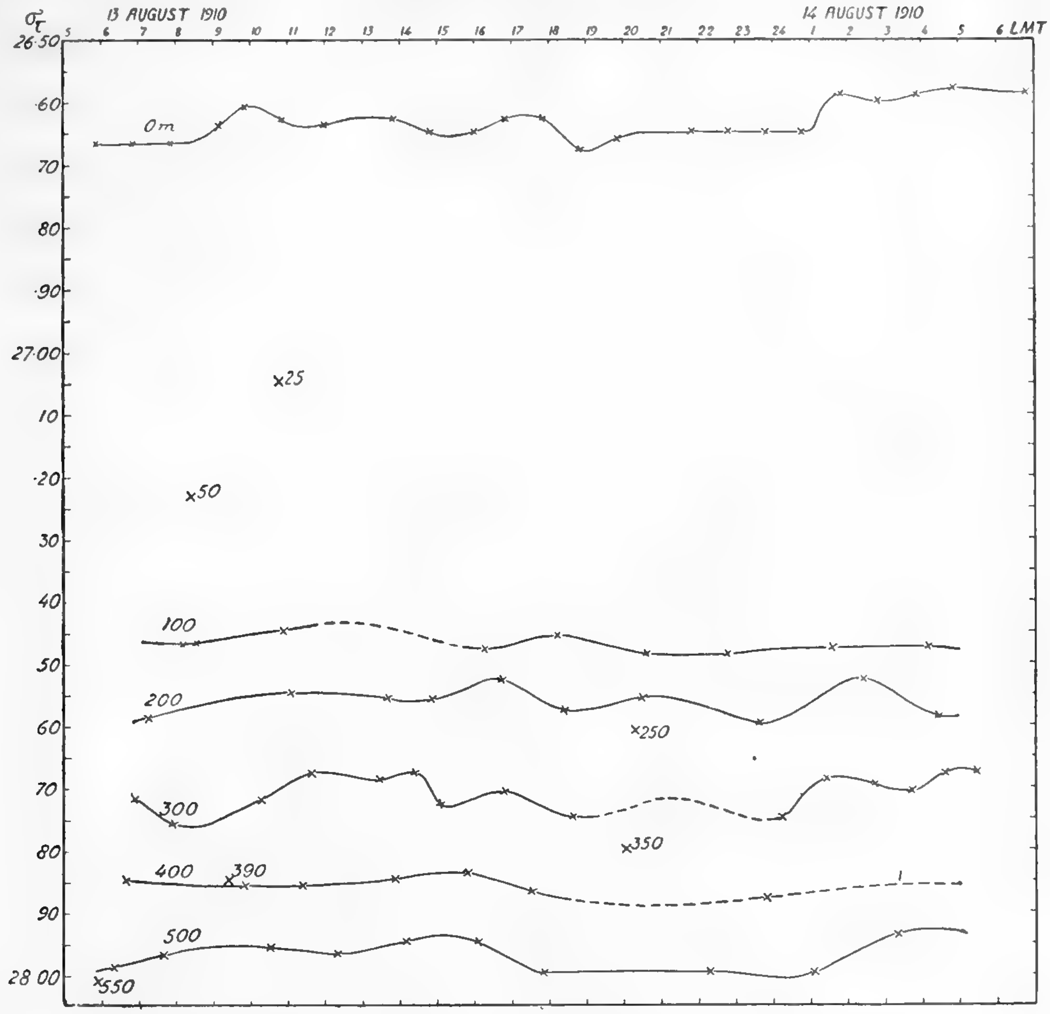
"M. S." STAT. 115. TEMPERATURE.



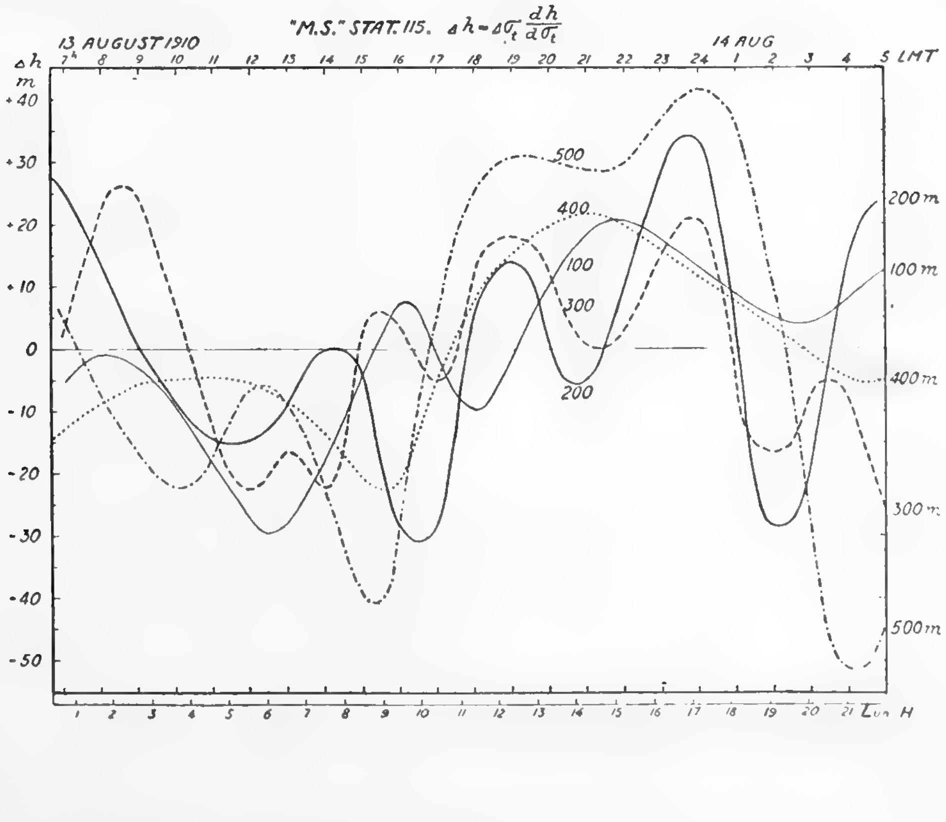
"M.S." STAT. 115: $\Delta h - \Delta\tau \frac{dh}{d\tau}$

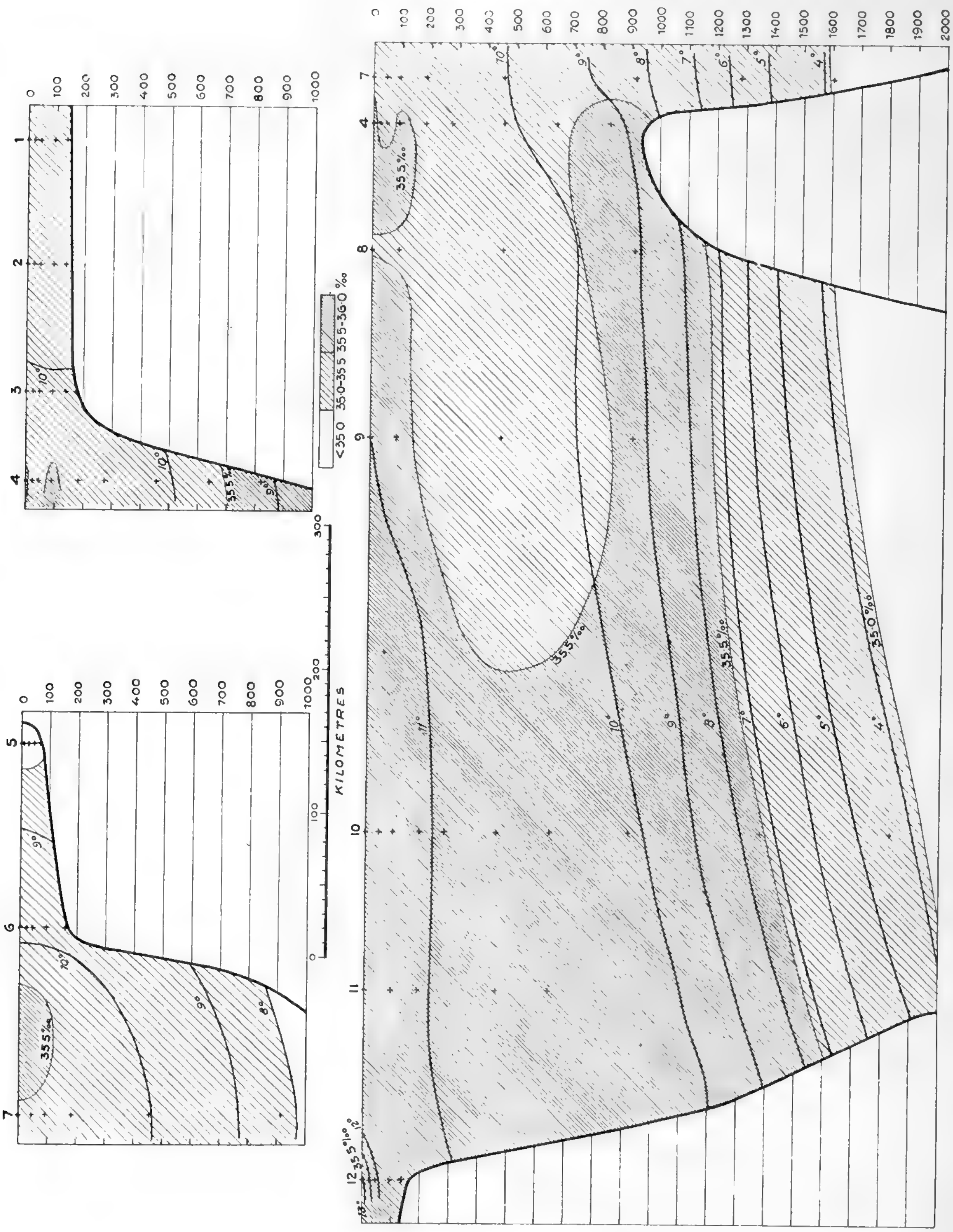


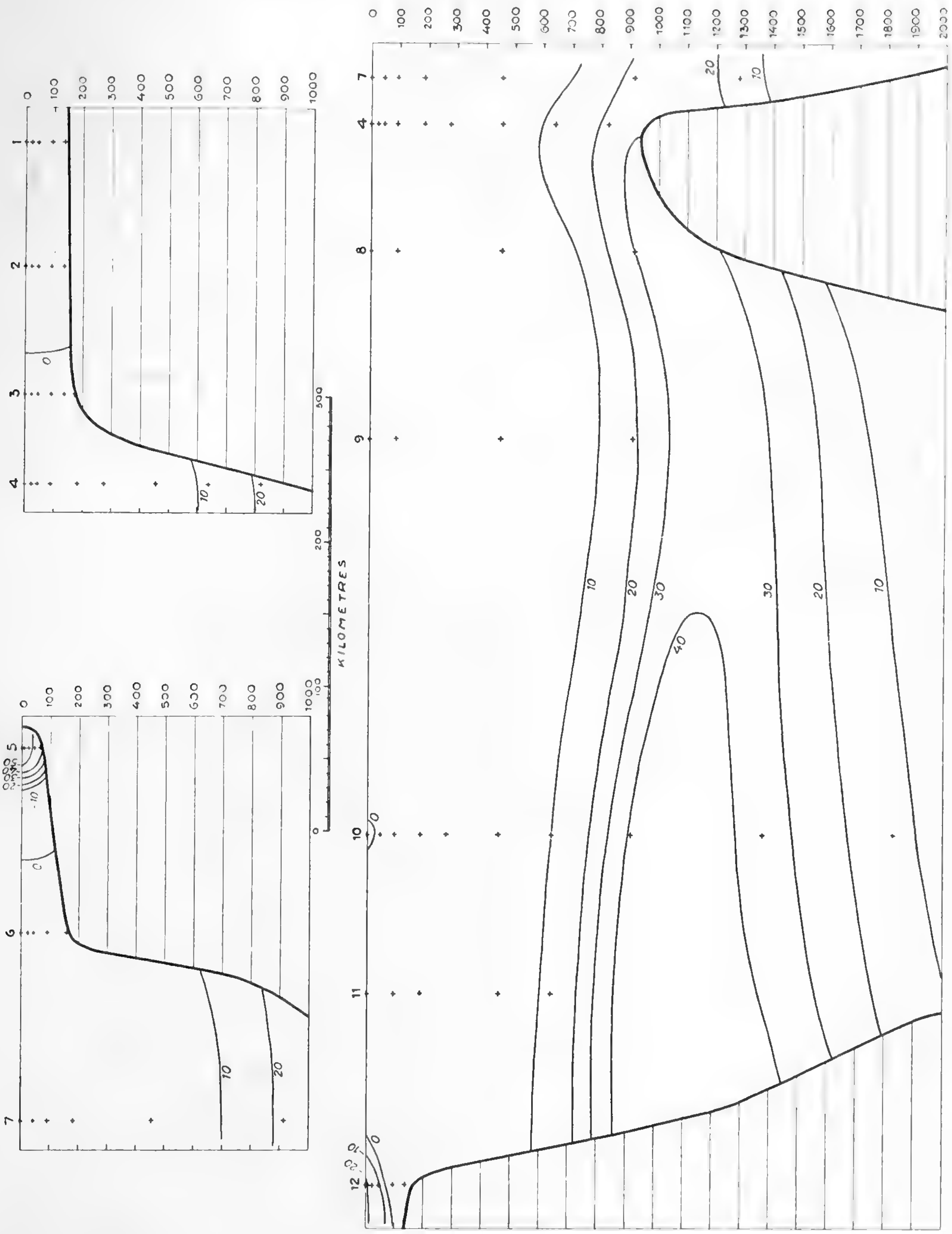
'M. S.' STAT. 115. DENSITY.

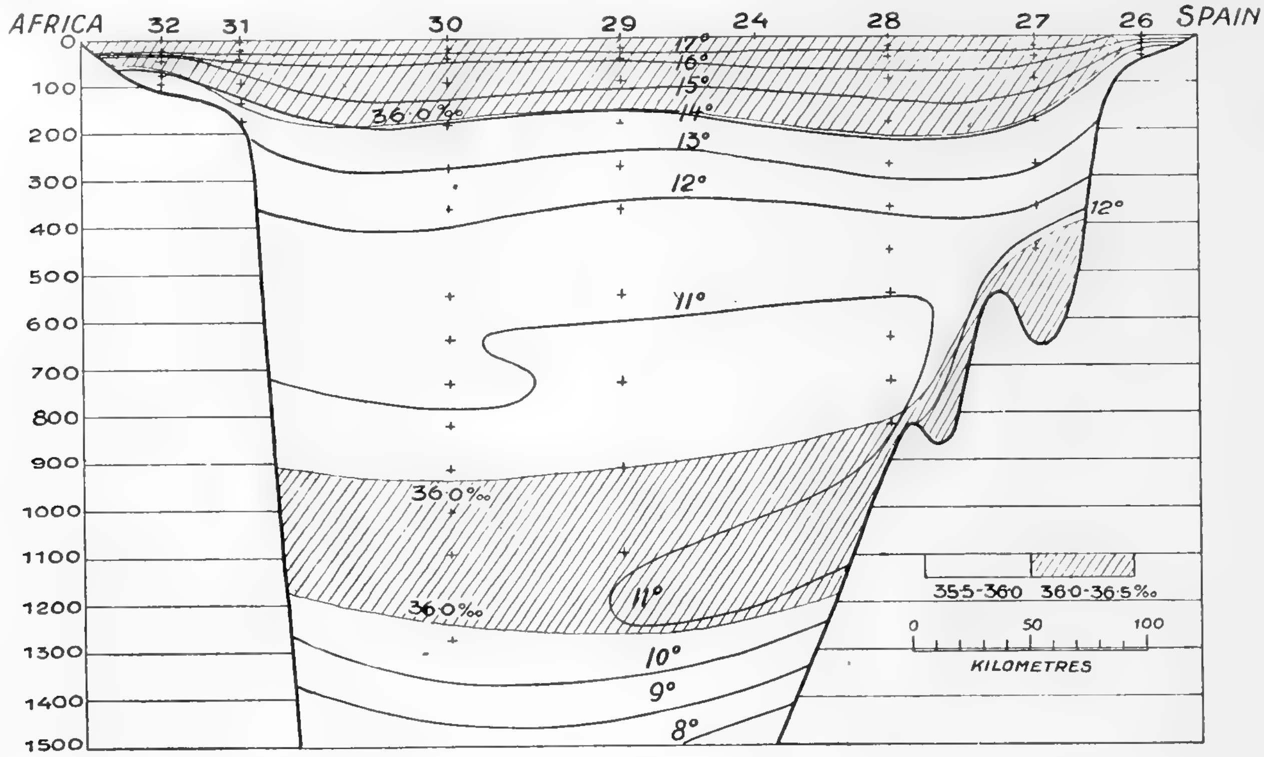


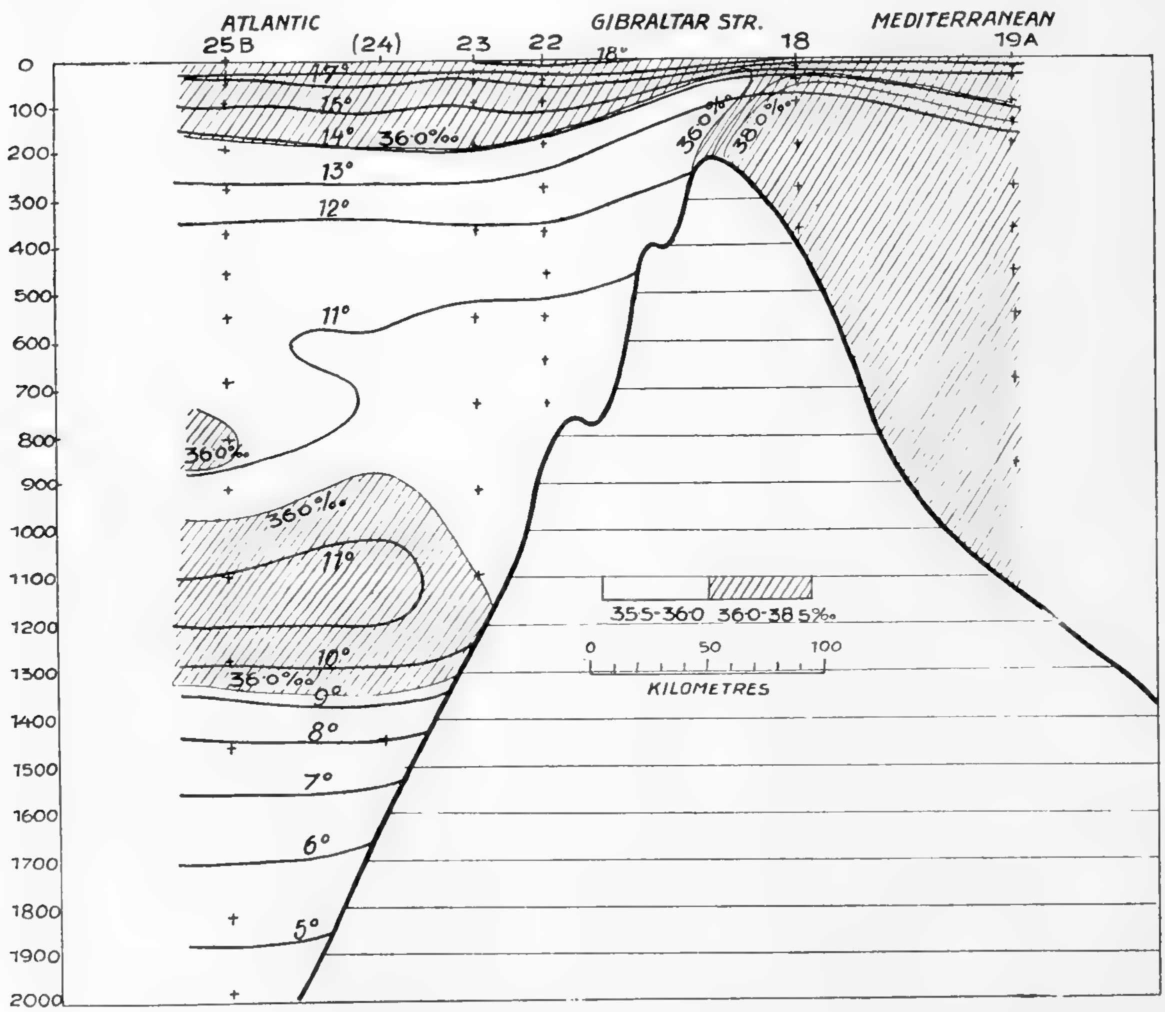
"M.S." STAT. 115. $\Delta h = \Delta\sigma_t \frac{dh}{d\sigma_t}$

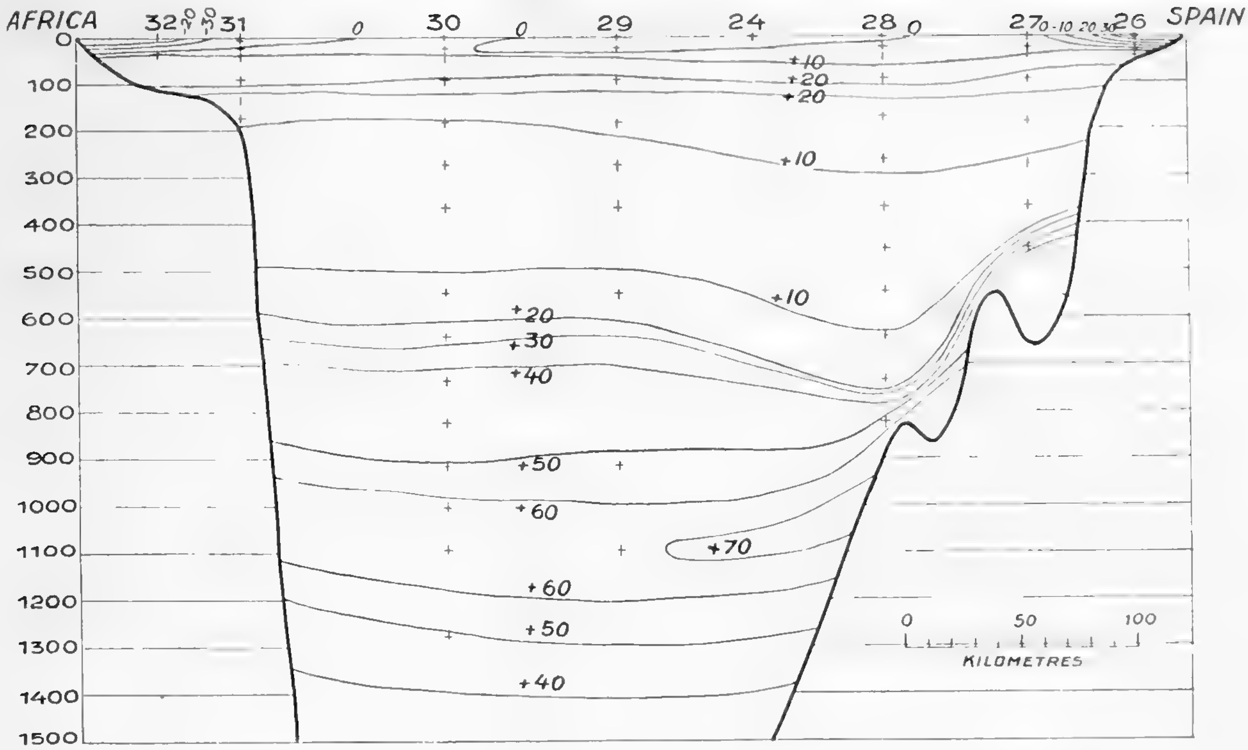


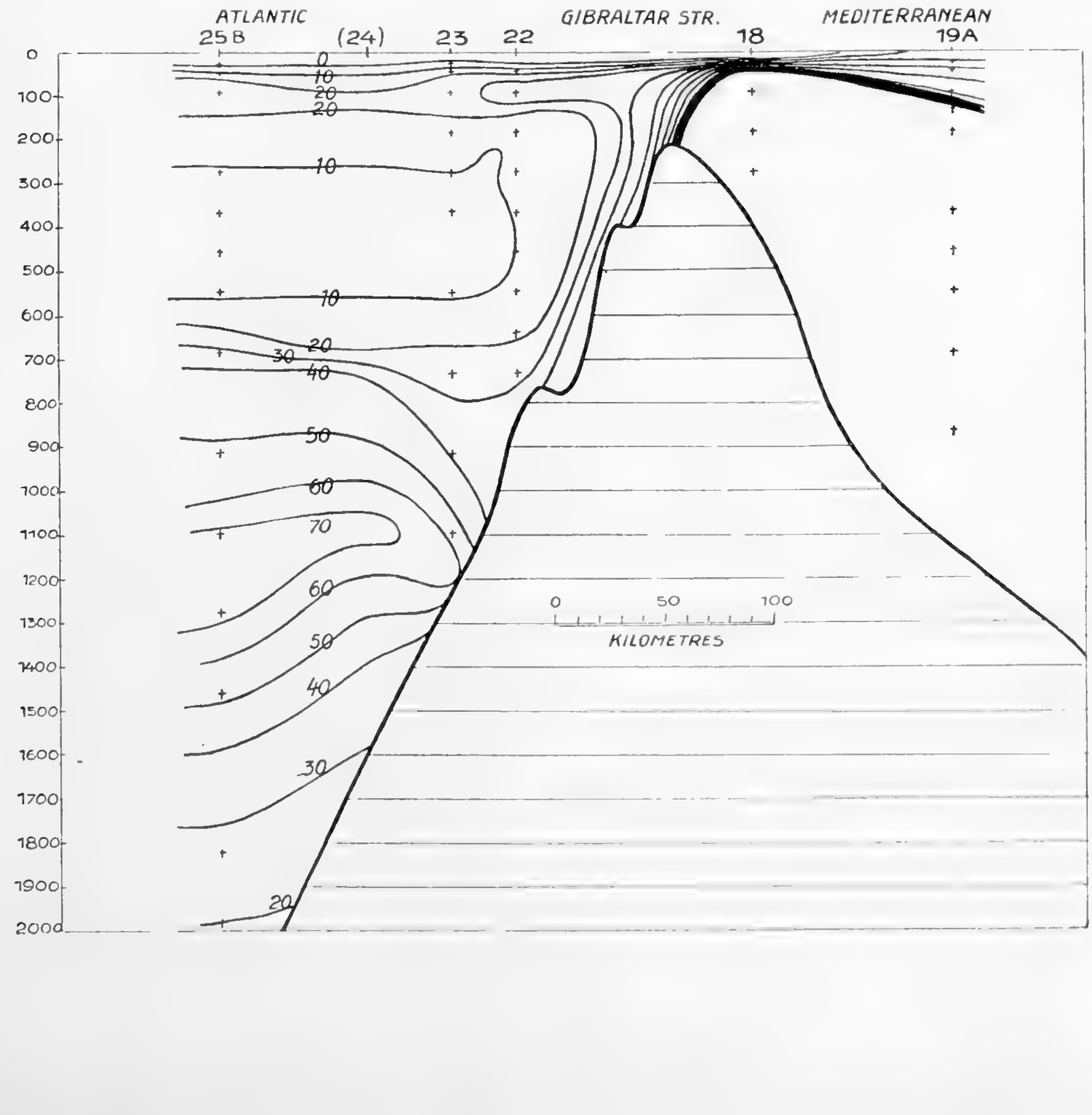

<35.0
35.0-35.5
35.5-36.0 ‰
KILOMETRES
35.5‰
35.0‰

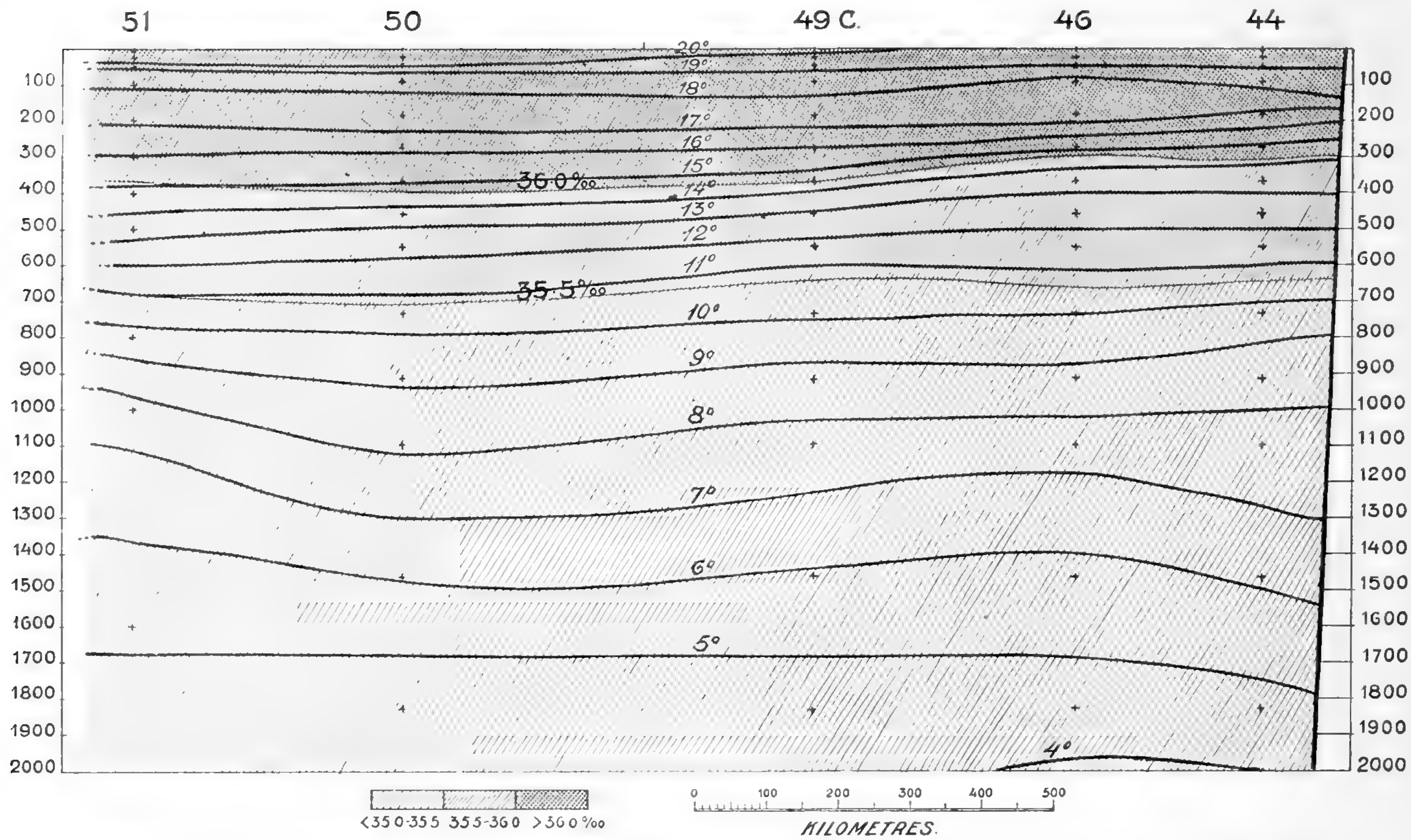

KILOMETRES

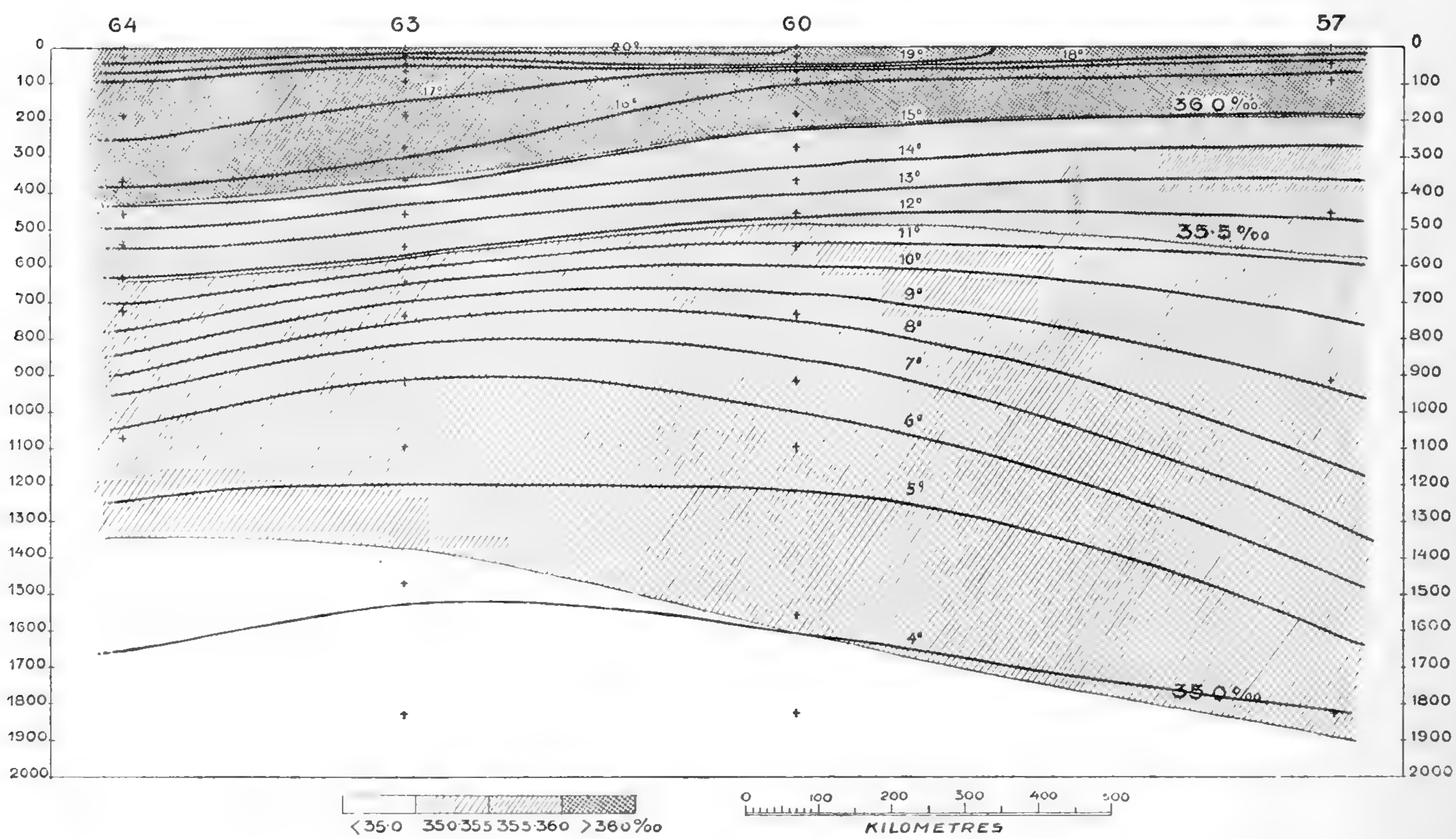

AFRICA
SPAIN
32
31
30
29
24
28
27
26
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
36·0‰
35·5-36·0
36·0-36·5‰
KILOMETRES

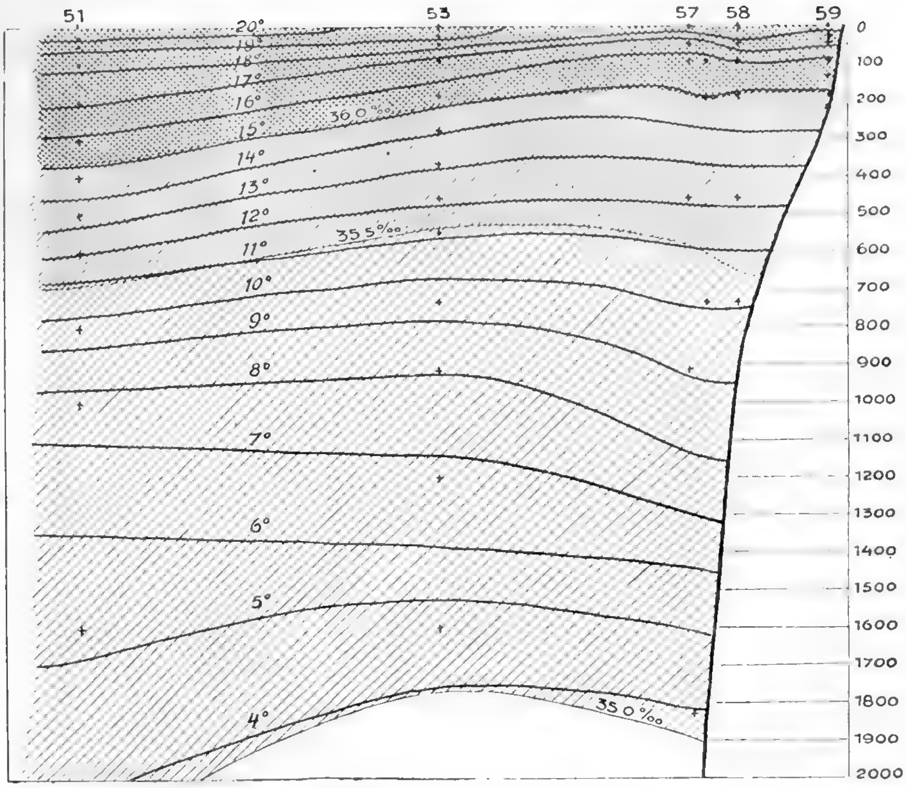

ATLANTIC
GIBRALTAR STR.
MEDITERRANEAN
25B
(24)
23
22
18
19A
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
36·0‰
38·0‰
35·5-36·0
36·0-38·5‰
KILOMETRES

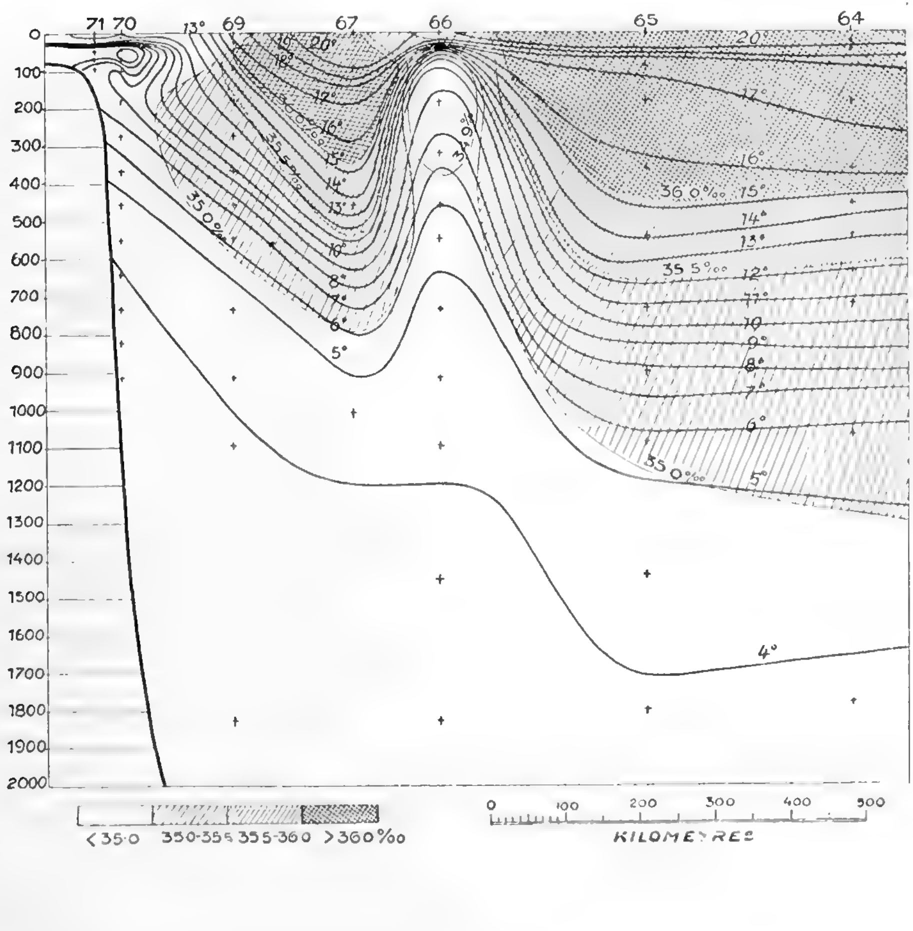

AFRICA
SPAIN
32
31
30
29
24
28
27
26
+10
+20
+30
+40
+50
+60
+70
KILOMETRES

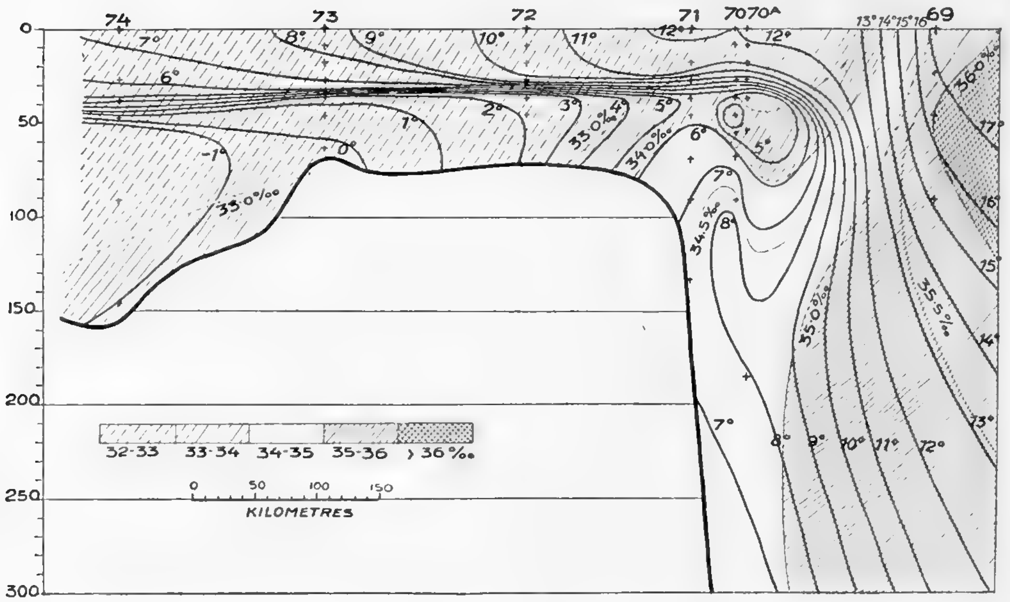

ATLANTIC
GIBRALTAR STR.
MEDITERRANEAN
25B
(24)
23
22
18
19A
KILOMETRES

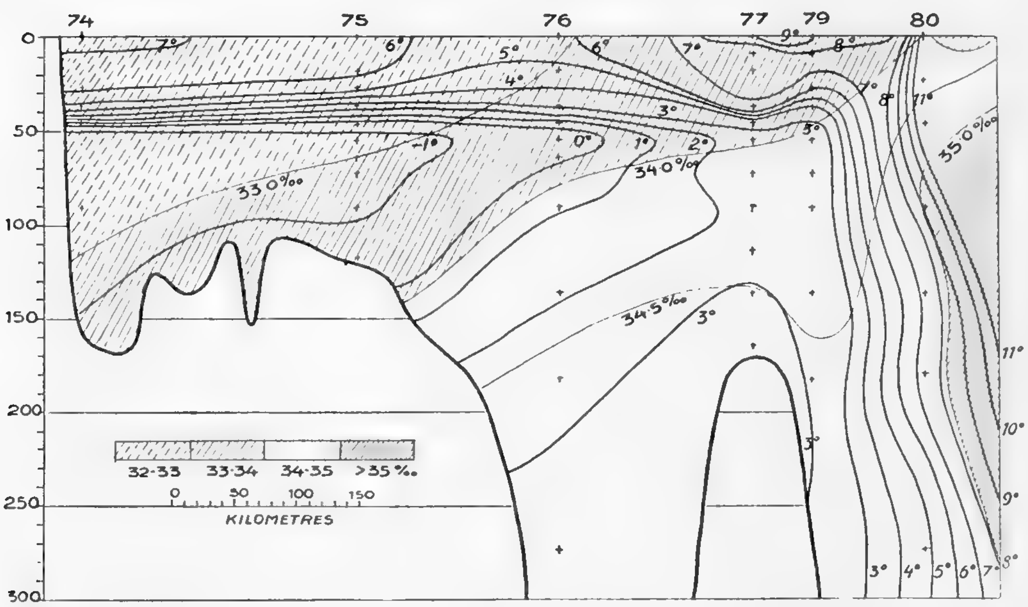

51
50
49 C.
46
44
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
36·0‰
35·5‰
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
<35·0-35·5 35·5-36·0 >36·0‰
0 100 200 300 400 500
KILOMETRES.

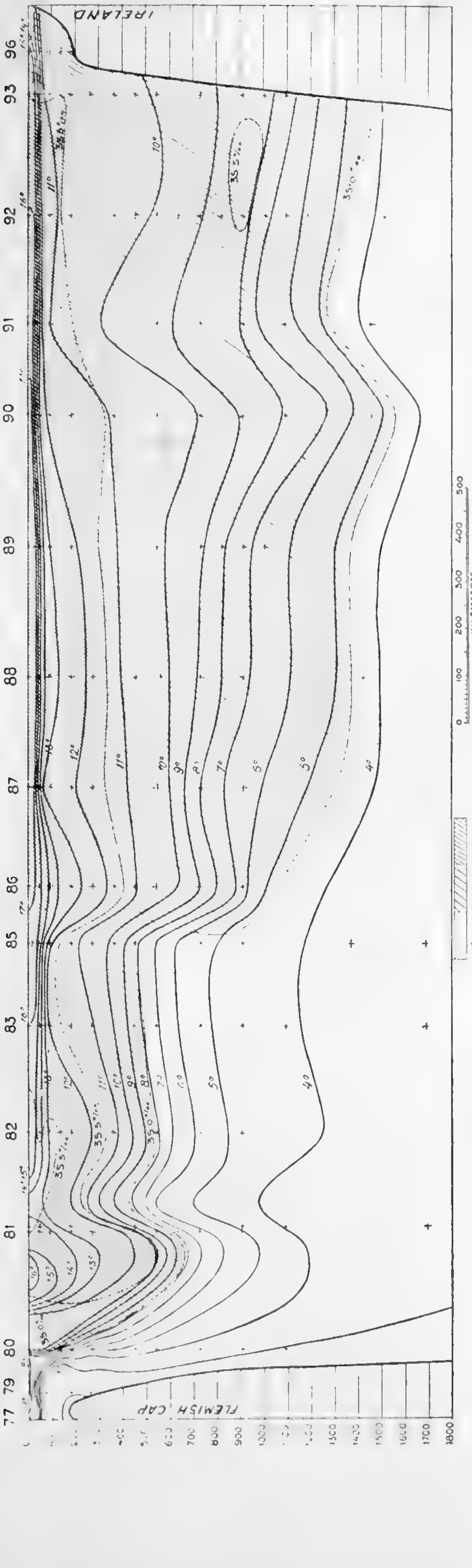

64
63
60
57
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
36·0‰
35·5‰
35·0‰
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
<35·0 35·0-35·5 35·5-36·0 >36·0‰
0 100 200 300 400 500
KILOMETRES

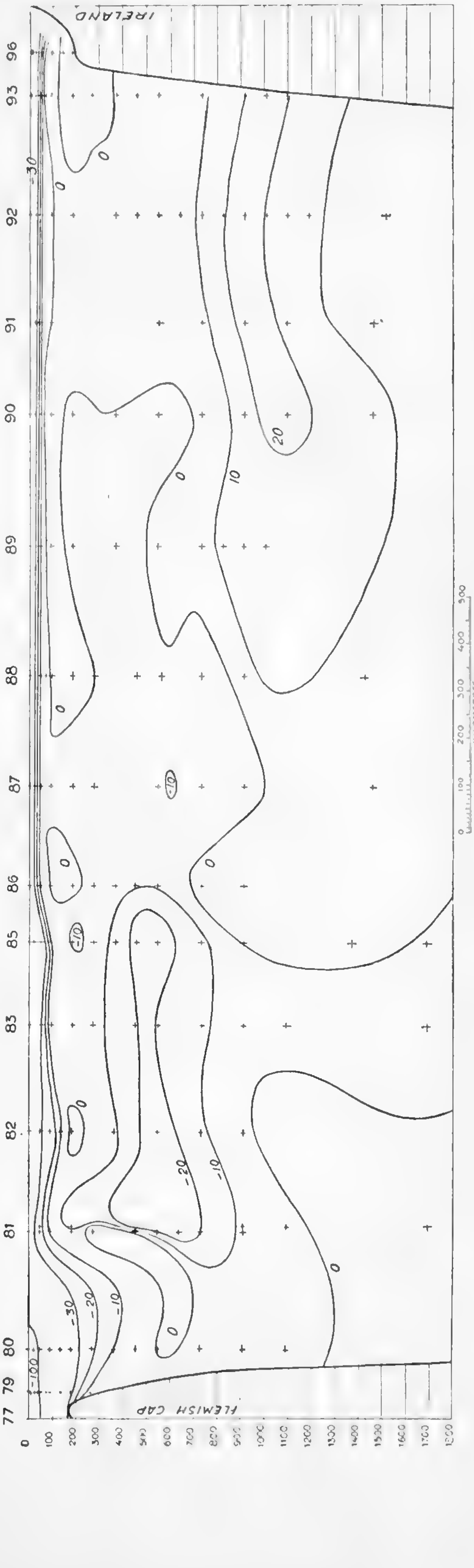

51
53
57
58
59
20°
19°
18°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
36.0‰
35.5‰
35.0‰
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

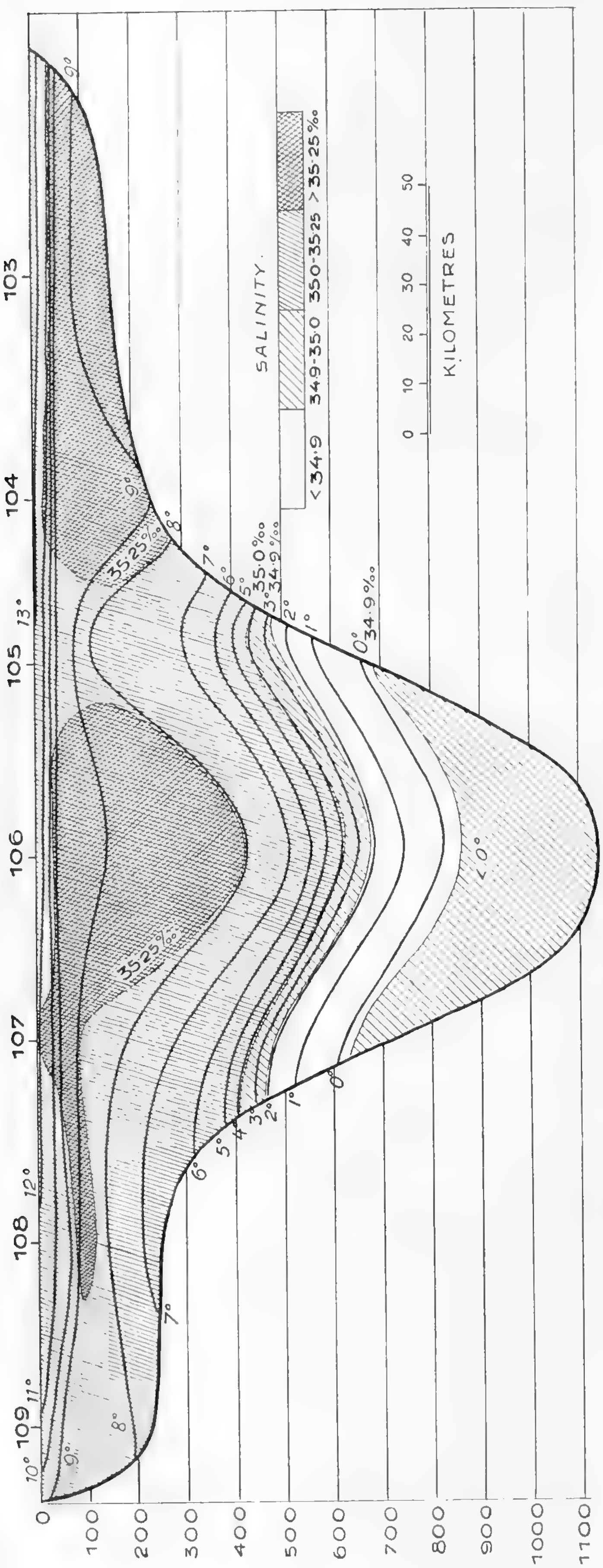

71
70
69
67
66
65
64
13°
20°
17°
16°
15°
14°
13°
12°
11°
10°
9°
8°
7°
6°
5°
4°
36.0‰
35.5‰
35.0‰
34.9‰
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
<35.0
35.0-35.5
35.5-36.0
>36.0‰
0
100
200
300
400
500
KILOMETRES


74
73
72
71
7070A
69
13° 14° 15° 16°
7°
8°
9°
10°
11°
12°
6°
2°
3°
4°
5°
1°
0°
-1°
33.0‰
34.0‰
34.5‰
35.0‰
35.5‰
36.0‰
17°
16°
15°
14°
13°
32-33
33-34
34-35
35-36
>36‰
0
50
100
150
KILOMETRES
0
50
100
150
200
250
300

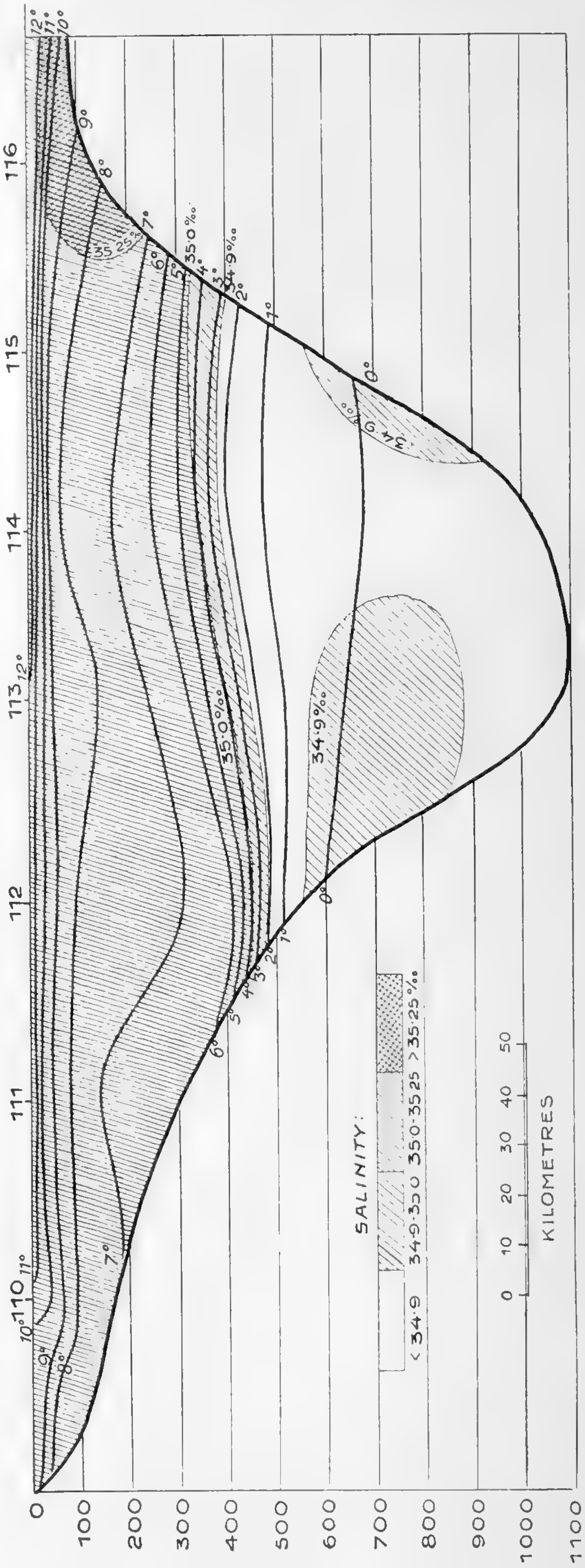

74
75
76
77
79
80
7°
6°
5°
4°
3°
8°
9°
11°
-1°
0°
1°
2°
33.0‰
34.0‰
34.5‰
35.0‰
10°
32-33
33-34
34-35
>35‰
0
50
100
150
KILOMETRES
0
50
100
150
200
250
300


IRELAND
FLEMISH CAP
KILOMETRES

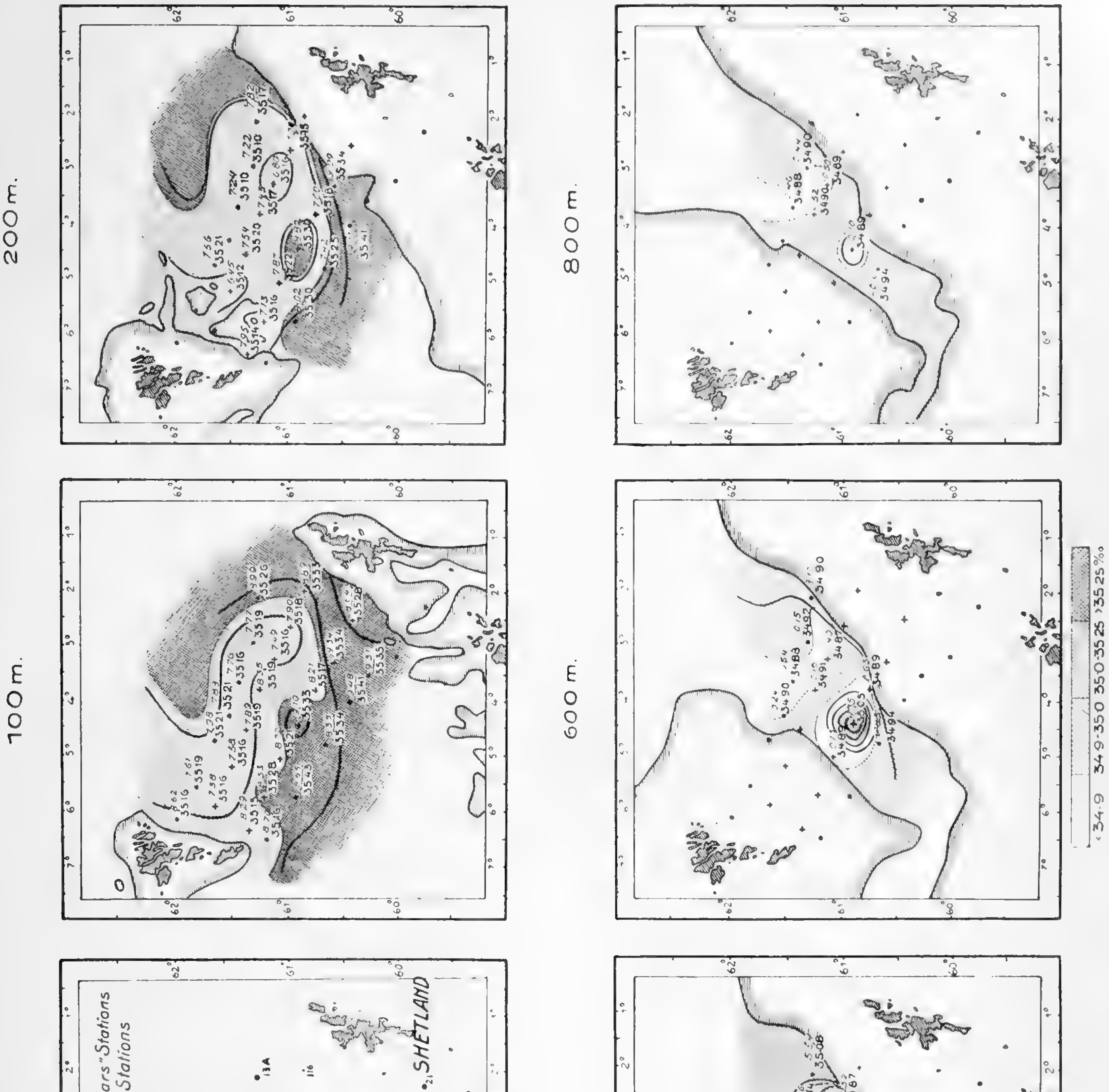

IRELAND
FLEMISH CAP
KILOMETRES



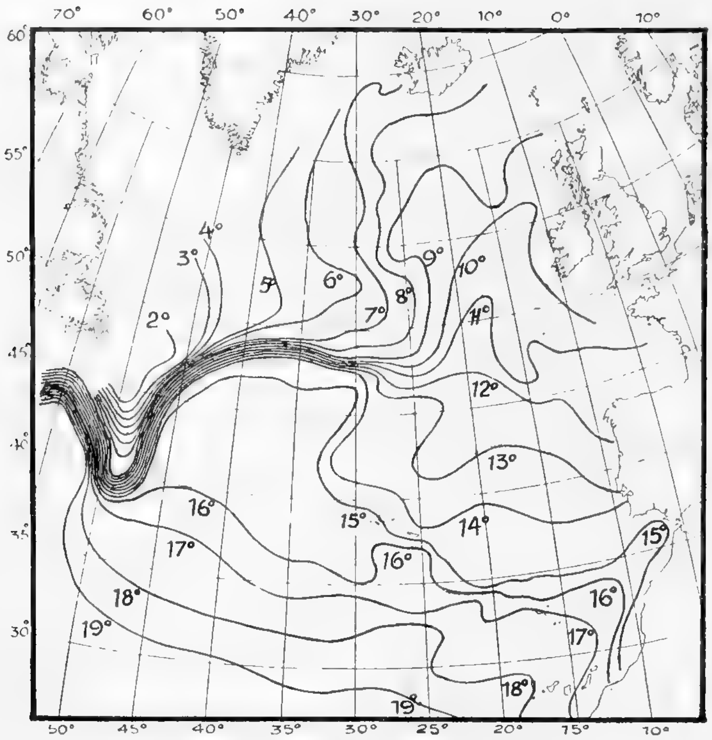
SALINITY.
<34·9
34·9-35·0
35·0-35·25
>35·25‰
KILOMETRES
0 10 20 30 40 50
103 104 105 106 107 108 109
0 100 200 300 400 500 600 700 800 900 1000 1100
35·25‰
35·0‰
34·9‰



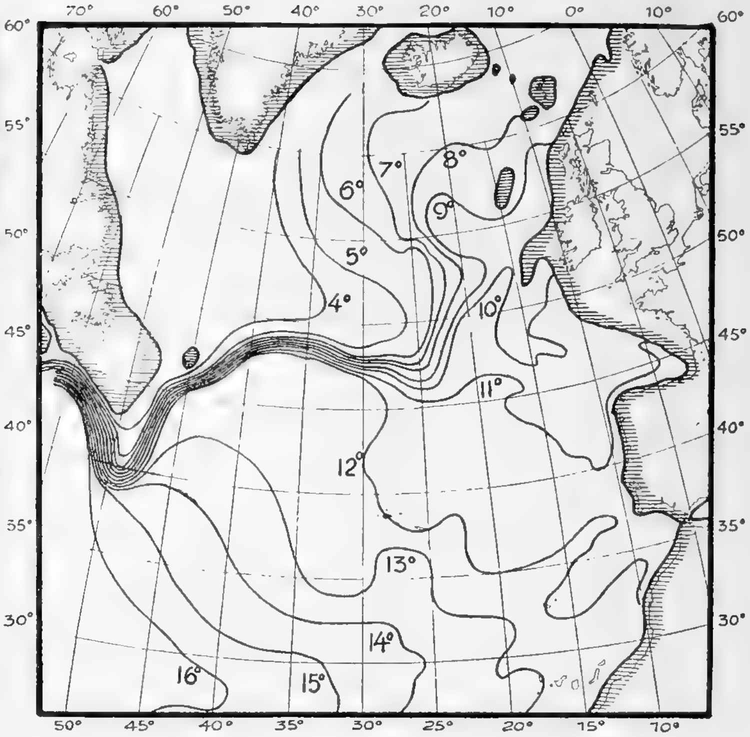
SALINITY.
<34·9
34·9-35·0
35·0-35·25
>35·25‰
KILOMETRES
0 10 20 30 40 50
110 111 112 113 114 115 116
0 100 200 300 400 500 600 700 800 900 1000 1100
35·25
35·0‰
34·9‰


200 m.
100 m.
Stations
800 m.
600 m.
400 m.
FAROES
SHETLAND
+ „Michael Sars" Stations
• Scottish Stations
<34.9 34.9-35.0 35.0-35.25 >35.25‰

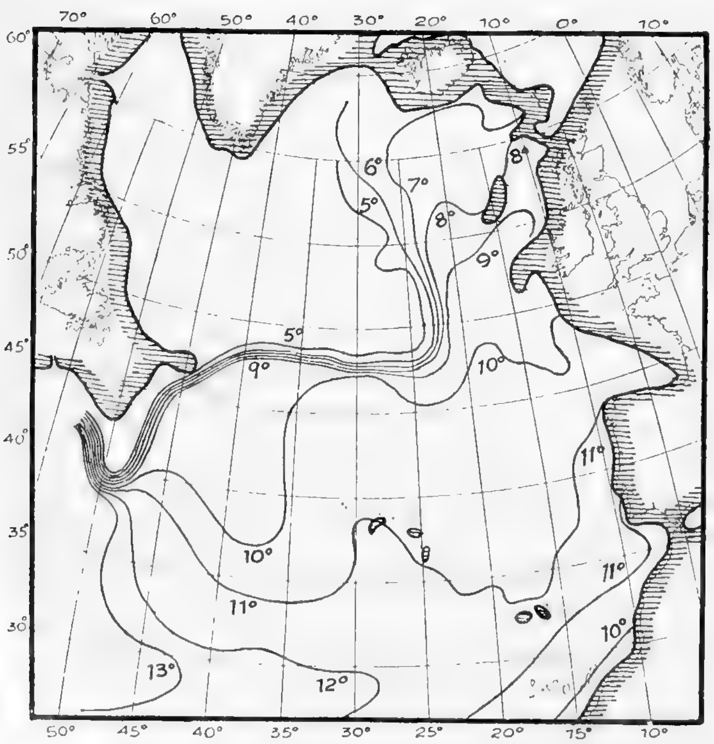
100 m.



400 m.

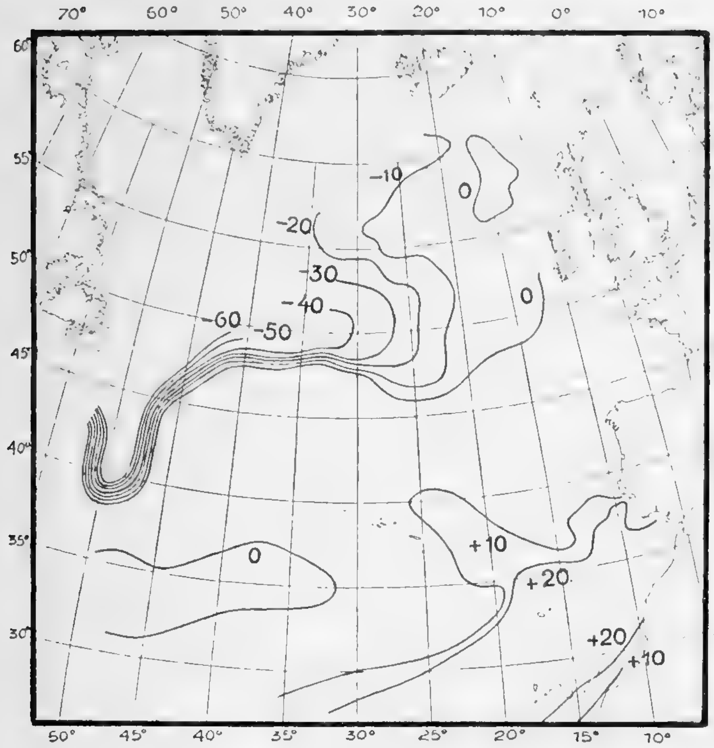


600 m.

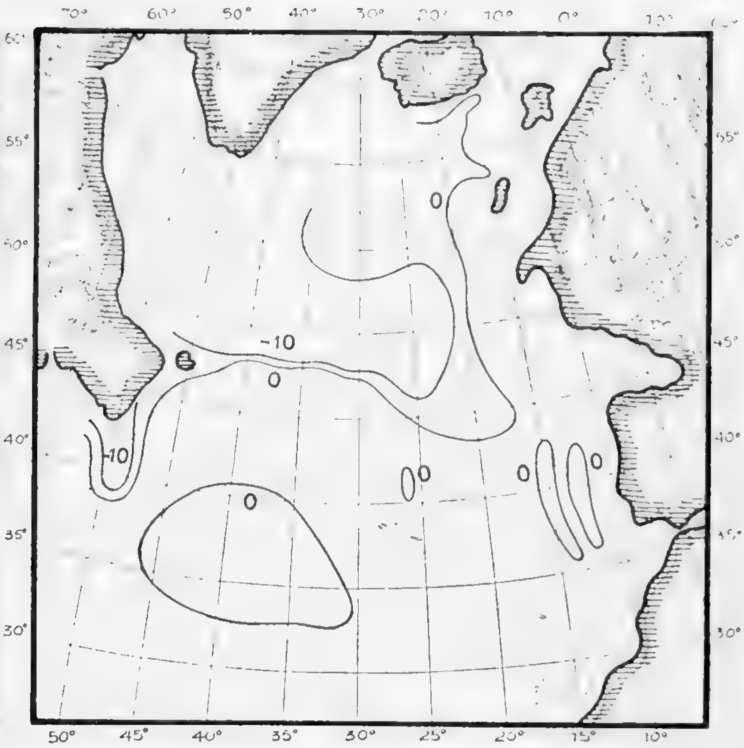


1000 m.

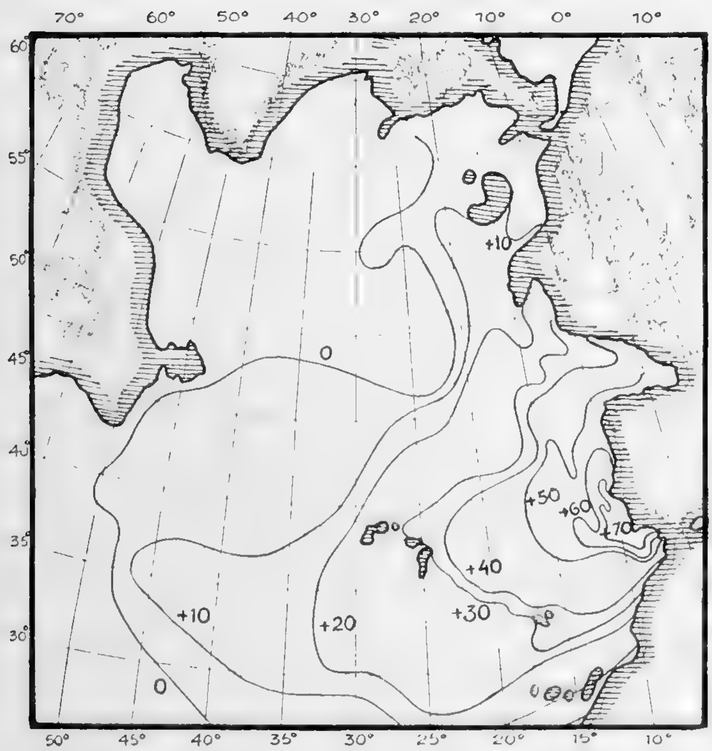
100 m.



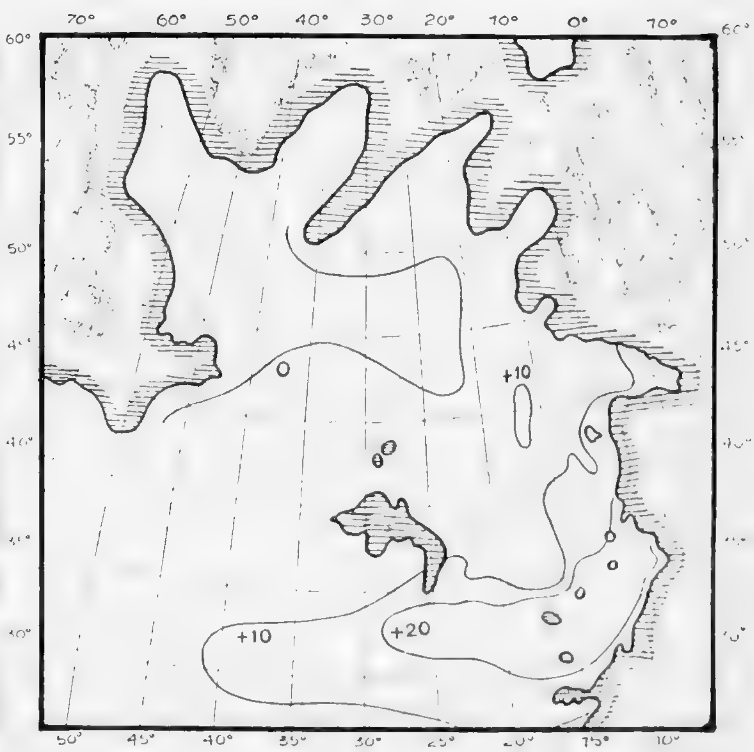
400 m.

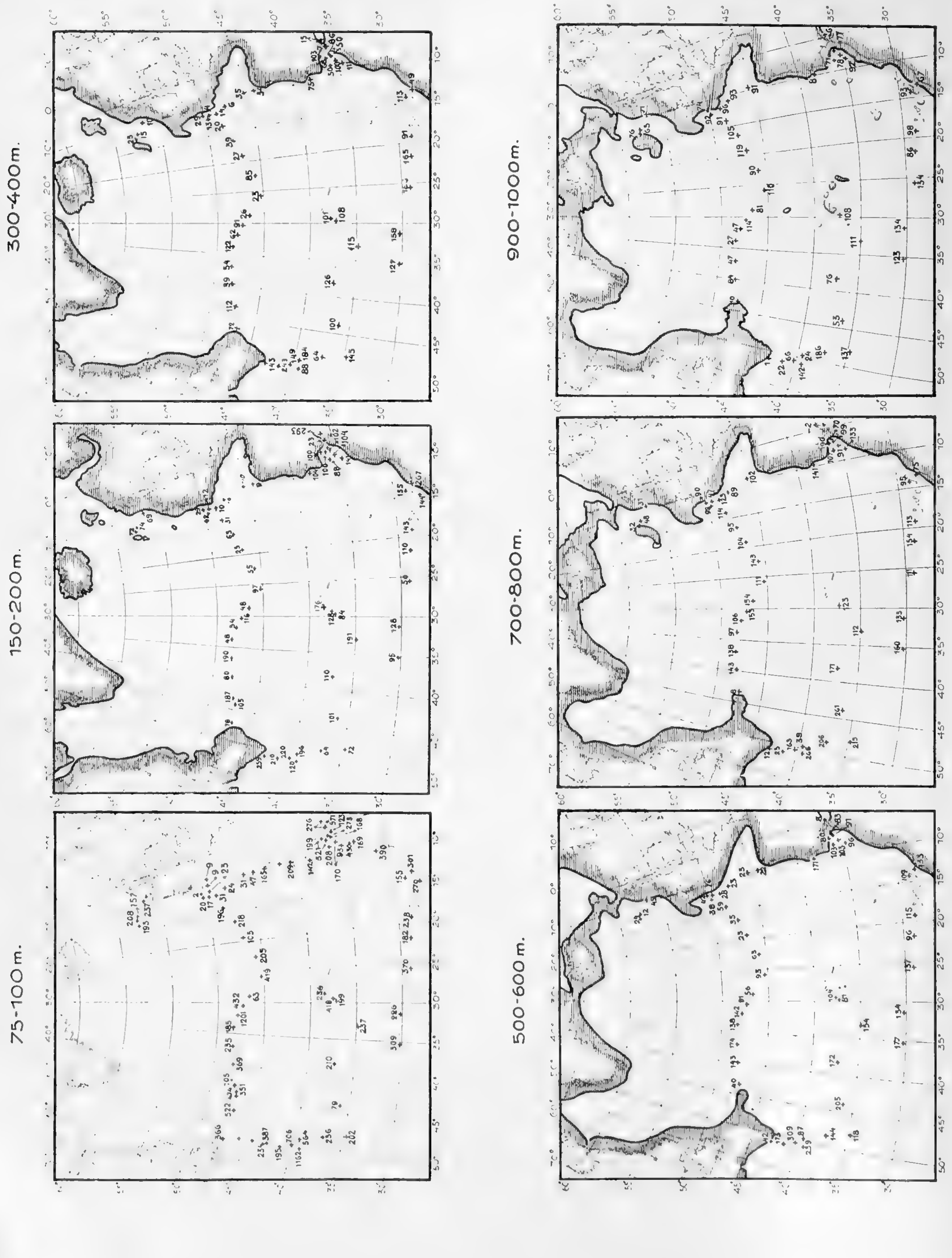


1000 m.



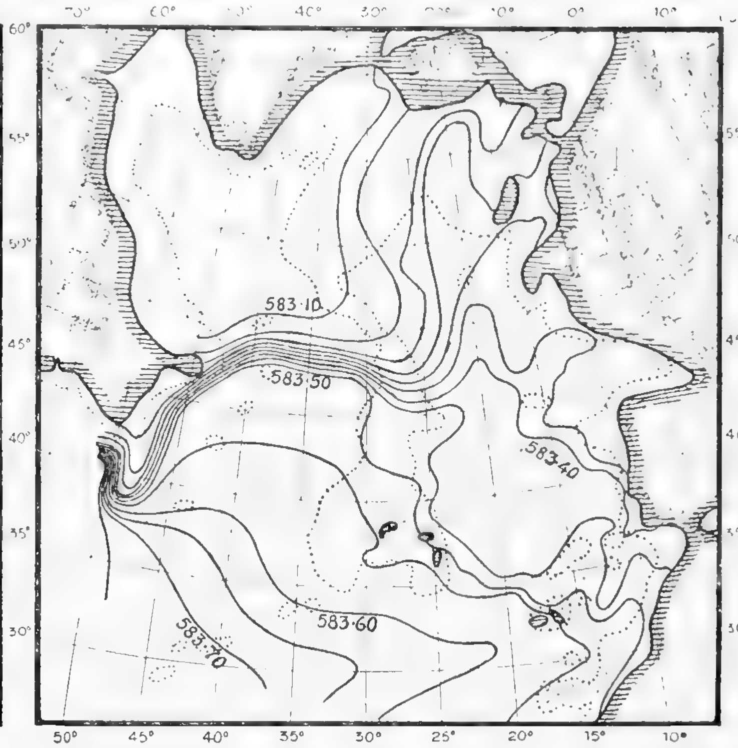
2000 m.



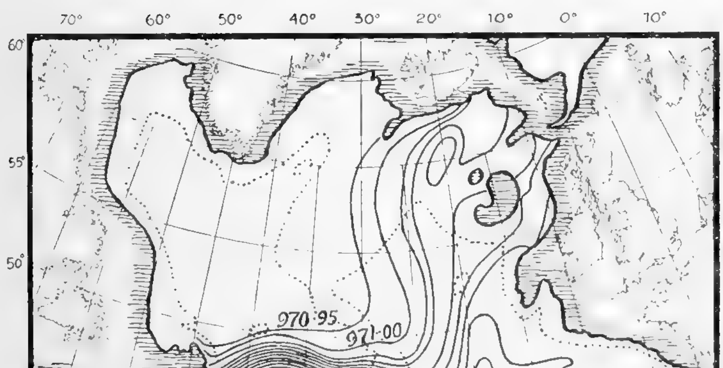

300-400 m.
150-200 m.
75-100 m.
900-1000 m.
700-800 m.
500-600 m.

200 d.-bars

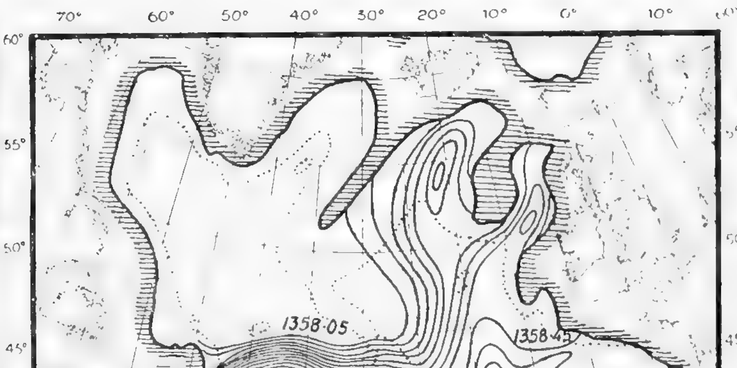
600 d.-bars



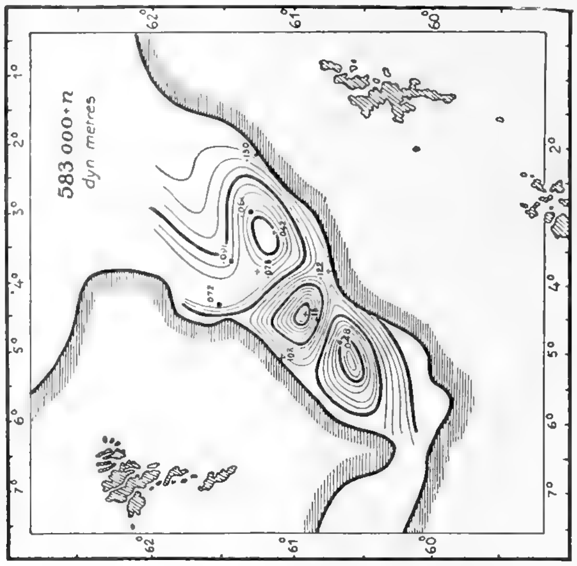
1000 d.-bars



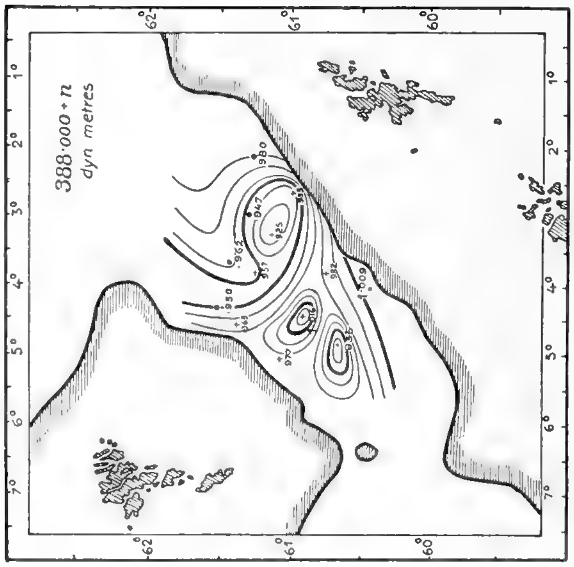
1400 d.-bars



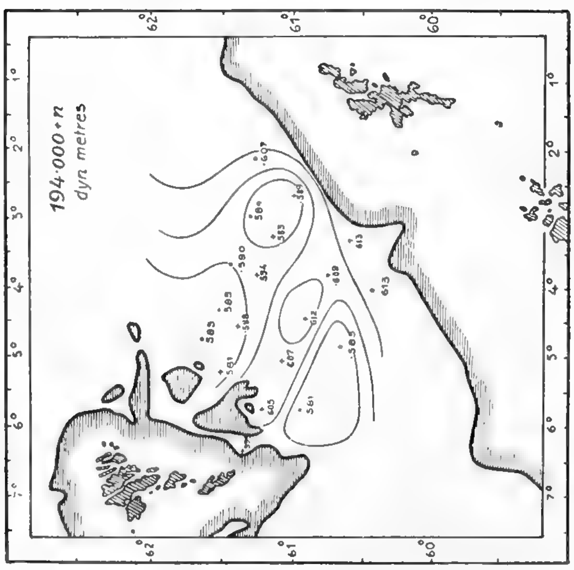
600 d.-bars

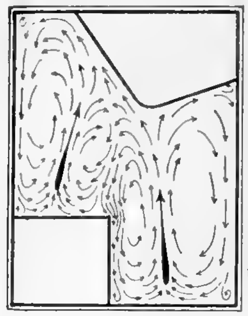


400 d.-bars



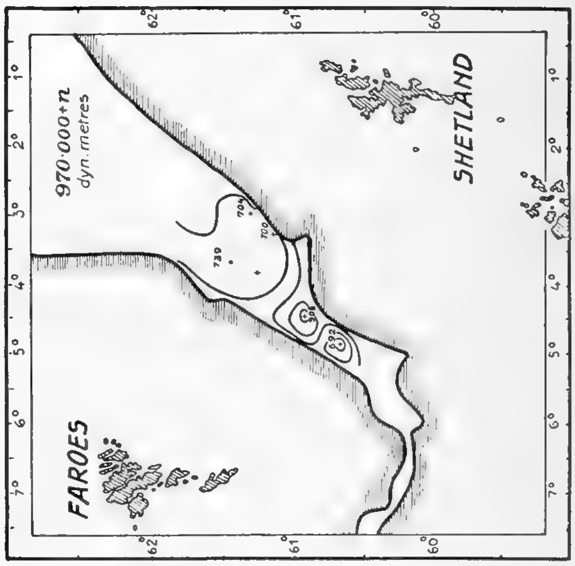
200 d.-bars



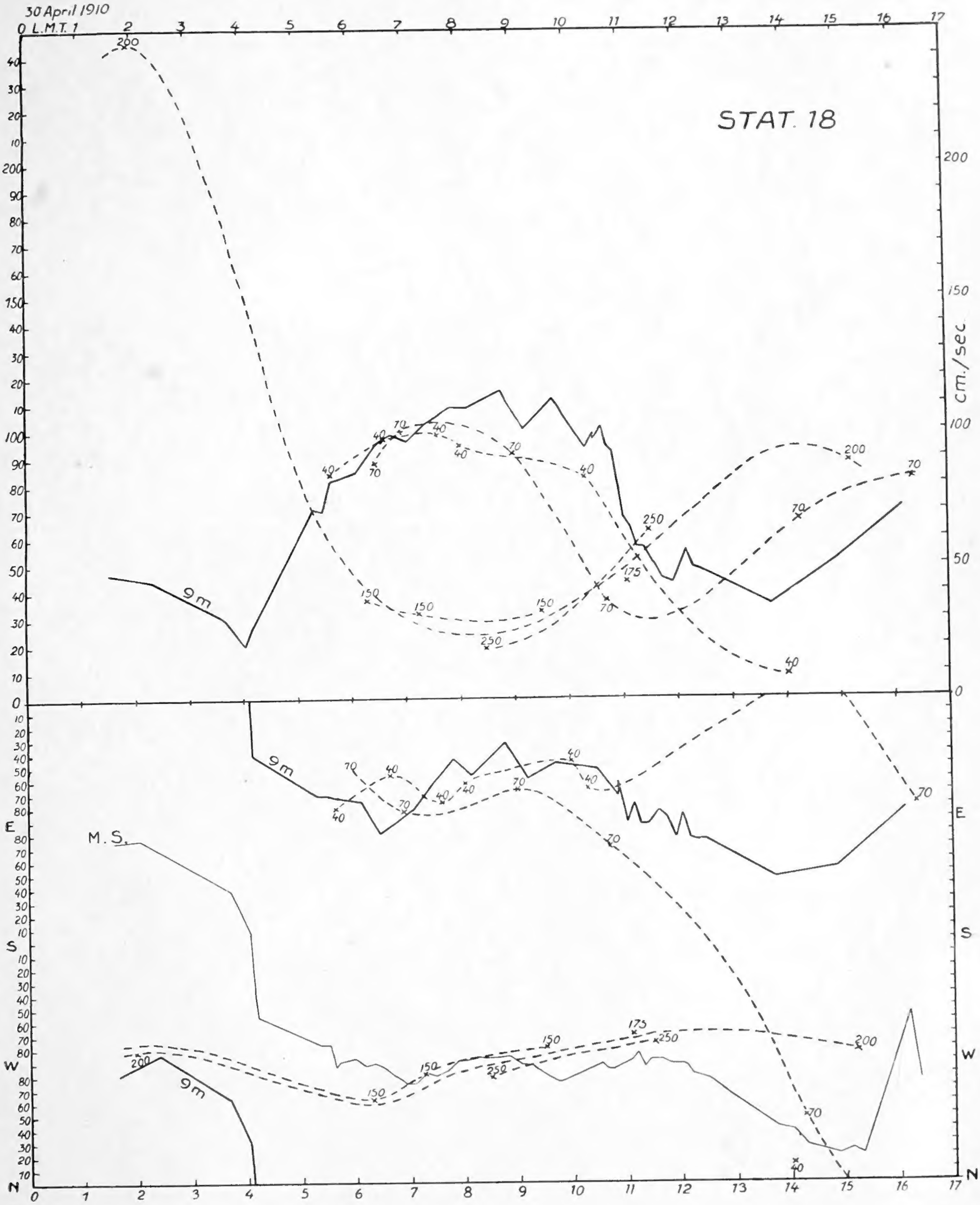


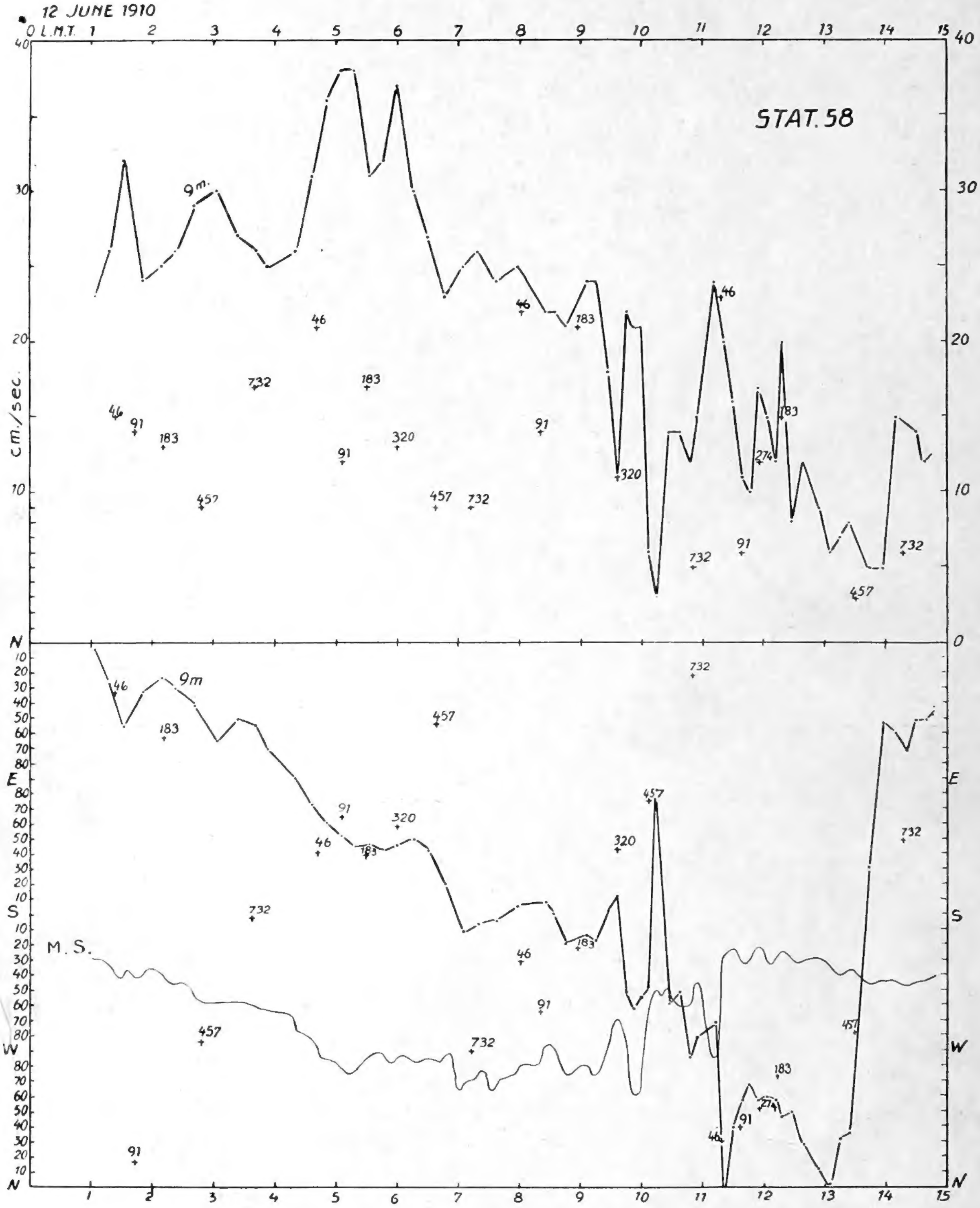
Experiment in Water-tank.
(Krümmel)

1000 d.-bars



800 d.-bars


30 April 1910
L.M.T.
STAT. 18
cm./sec.
9m
M.S.
E
S
W
N


12 JUNE 1910
0 L.M.T. 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
STAT. 58
cm./sec.
9m.
46
91
183
320
457
732
274
M. S.
N
E
S
W
10 20 30 40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

) horizontal hauls with pelagic trawls and 18 hauls with a large tow-net. *Trawlings* ndertaken on twenty-four occasions at different depths.

The publication of the report on the scientific results achieved by the expedition undertaken by the Bergen Museum. In addition to hydrography, the systematic, l and geographical results, in particular, will form the chief contents of the report, the more detailed anatomical studies to be printed in other publications. The ill be issued in English. It will be profusely illustrated with plates, some of which coloured, in addition to figures and charts printed in the text.

The printing of the report had already begun, but the war, the great fire in Bergen, financial difficulties which followed upon the war placed obstacles in the way of its ion. As these difficulties have now been surmounted, its issue is being resumed.

The report will be published in parts as the manuscripts are received by the editor.

or the terms upon which subscribers may obtain this publication the editorial e would refer to the appended announcement by the publishers, A-S John Grieg, undertaken the issue and sale of the work.

Bergen, Norway.

For the Trustees of the Bergen Museum

C. Geelmuyden. *H. P. Lie.* *C. F. Kolderup.* *A. Brinkmann.*

---

he report will be printed in accordance with the particulars given above. Each r half volume will be sent to subscribers on publication, and will be paid for on t. The price of each issue — volume or half volume — will be £ 3, the total cost ranteed not to exceed £ 30.

subscriber is bound to take the entire work.

purchase of single volumes or parts thereof will not be permitted.

enquiries regarding the subscription should be addressed to the publishers:

A-S John Grieg, Bergen, Norway.

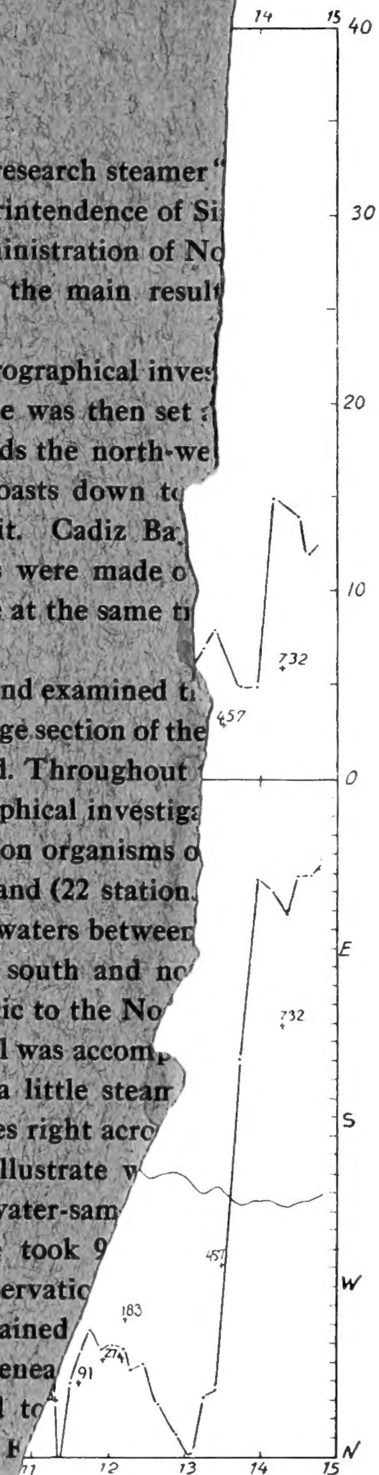
During the months of May to August 1910 the Norwegian research steamer "
Sars" accomplished a cruise in the North Atlantic under the superintendence of Si
Murray, K. C. B., and Dr. Johan Hjort, director of the administration of No
fisheries. Dr. Hjort has published a short review of some of the main result
cruise,[1]) in which he says:

We first experimented with the trawl, and undertook hydrographical inves
to the west of Ireland, over the slope of the coast banks. Our course was then set
Bay of Biscay, where we made a number of investigations, towards the north-we
of Spain. From there we followed the Spanish and Portuguese coasts down to
where we obtained a series of current measurements in the strait. Cadiz Ba
examined and careful hydrographical observations of the currents were made o
sections of these interesting waters, while series of trawlings were at the same ti
taken from the coast down to profound depths.

We then steamed in the direction of the Canary islands, and examined t
banks from the coast to the ocean floor, and subsequently crossing a large section of the
visiting the Azores, the Sargasso sea, and eventually Newfoundland. Throughout
of this section, comprising 40 stations, we made constant hydrographical investiga
employed many different kinds of instruments for collecting plankton organisms o
A similar section was run in July from Newfoundland over to Ireland (22 station
concluded our researches by a more thorough examination of the waters between
Rockall, the Faroes and Shetland—that is to say, the sea to the south and no
Wyville Thomson ridge—to study the transition from the Atlantic to the No

During the four months that the cruise lasted a great deal was accomp
oceanographic science it cannot but be interesting to learn that a little stean
226 tons, could carry out so many and such multifarious researches right acro
great ocean basins, and I will accordingly give a few figures to illustrate w

In the case of *hydrographical* material we collected 2400 water-sam
900 of which were from below the surface. At 110 stations we took 9
observations from below the surface, while as many as 1625 observatio
temperature were recorded during the cruise. In addition, we obtained
of currents and seven measurements of the penetration of light benea
the study of *vegetable plankton* we made 140 vertical hauls, and to
for filtration and 58 samples for examination with the centrifuge. F
there were 95 vertical hauls with nets of different sizes, 193 hor



[1]) The Geographical Journal for April and May 1911.
Internationale Revue der gesammten Hydrobiologie und Hydrograph